United States Department of Agriculture
Soil Conservation Service
P.O. Box 2890
Washington, D.C.
20013

August 22, 1984

TECHNICAL RELEASE NO. 46
210-VI
AMENDMENT 1

SUBJECT: ENG - GATED OUTLET APPURTENANCES, EARTH DAMS

Purpose. To transmit replacement pages for Technical Release No. 46.

Effective Date. This amendment is effective when received.

Changes have been made to several pages in the technical release due to revised policy and criteria and also as a result of knowledge gained since its issue. The changes are identified by vertical lines in the page margins.

A copy of this amendment is to be provided to each holder of Technical Release No. 46. These changes will be incorporated into the next reprinting of the technical release.

Distribution. Additional copies are available from Central Supply by ordering stock no. TR-46-Am. 1.

Filing Instructions.

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Gerald D. Seinwill

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Enclosures

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REMARKS

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SECTION A - INTRODUCTION

This design manual contains procedure, design aids, standard details and drawings, useful for developing construction drawings for gated outlets and appurtenances common to earth dams used for storage of water for irrigation.

Design aids in the form of nomographs, charts and tables have been developed wherever possible to provide ready solution of design analyses. Examples have been placed on each of the more complex charts and nomographs to facilitate their use and help the designer grasp the relationship between dependent variables in identifying most alternatives.

Some of the figures may appear complicated and require some study of the example to understand the relationships expressed. Once master of a chart, the designer has a comprehensive understanding and perspective of the relationship between elements attainable in no other way.

Each section of the manual is presented in adequate detail for treatment of its specific subject in design of small irrigation storage structures. An example is continued through the manual. As each section is finished, the progressive example is completed to include the system components discussed in that section.

The hydraulics section is a general treatment of hydraulic design of gated outlet systems. It is in adequate detail for preliminary design purposes and in many cases satisfactory for final design. Refined analysis is recommended where critical design factors and cost alternatives are involved.

Discussion of hydraulic systems for operation of control gates on earth dam conduits is presented in detail since the application is somewhat unique. The hydraulic system offers advantages under certain conditions over the mechanical gate stem control that makes it worth consideration.

The importance of proper conduit design and installation cannot be overstressed to insure safety of the structure. It is usually impractical if not impossible to repair deficiencies in conduits through embankments; this unit of the system must be done right the first time. Every item presented in this section deserves careful consideration.

Outlet structures for stilling high velocity flows from conduits have taken a variety of forms depending on physical and economic factors of the site and structure. Performance characteristics, general site adaptability and economic consideration to facilitate judgment in decision between alternate choices is presented. The several de :gn charts eliminate many steps and hours of work for quantity and cost est: ;ating.

Perhaps the most time saving operation in this manual is the summary sheet and procedure for preparing construction drawings. This concluding step opens the door to the several alternatives and considerations in composing a set of construction drawings for gated outlet appurtenances for earth dams.

Clarity of construction plans that present the design decisions made in preceding sections of the manual is important. Neatness, legibility and clarity in plans create a psychological response in the builder conducive to better quality work than the response to poorly drafted and vaguely presented details. The ideas offered permit maximum clarity and minimum effort to make a professional presentation of plans, consistent with the quality of design and helpful to both builder and construction engineer in getting a good job done.

It is beyond the scope of this manual to evaluate storage requirements and downstream water needs. In this respect each installation is unique and cannot be standardized. Embankment analysis has also been omitted as a subject requiring individual attention.

The concept of the STANDARD DAM for purposes of hydraulic design is a basic embankment shape and a full reservoir discharging at the toe of the dam through a conduit. As used in this manual, the cross section of the standard dam consists of an upstream slope of 3:1, a top width* of 2 H + 5 feet, and a downstream slope of 2:1. The standardized inlet, stem pedestal and lift pedestal are detailed for the 3:1 slope. Hydraulic losses are based on a conduit length associated with the described embankment profile, full reservoir, and a free outfall. Where these basic conditions exist, Figures B-1, 2, 3, 4; C-4, 5; F-1, 2, 3, 4, and 11 are intended to provide a preliminary design.

Conditions illustrated in Figure A-1, Equivalent Dam, i.e., extended conduit, submerged outlet, or part-full reservoir, suggest the use of Figures B-5 through B-10. For more unusual flow requirements, Figures B-11 through B-17 can be used to select components and sizes or to refine preliminary selections.

An overall perspective of the manual content and use is presented in Figure A-2, Procedure Flow Chart. This chart follows the normal sequence in selection and development of the details of gated outlet appurtenances. It shows the major decisions that might affect alternate selection required at various points in the development.

* The difference between this top width compared with one based on $\frac{H + 35}{5}$ will have little effect on the preliminary hydraulic proportioning of the conduit.

SECTION B - HYDRAULICS

I. INTRODUCTION

Selection of the proper gate and outlet conduit size is based on a comparison of several requirements:

1. Early season bypass of base flows with full reservoir head.
2. Pass the required irrigation flows with the reservoir at a level associated with the irrigation season.
3. Pass the late-season base flow with minimum reservoir level.
4. Evacuation requirement of state or regulatory agencies.
5. Minimum construction requirements of SCS TR-60, Conservation Practice Standard 378, or a regulatory agency.

The size that will meet condition 2 above will be capable of passing a much larger flow with full head and maximum gate opening. It must be determined that the energy of this flow can be safely controlled in the vicinity of the outlet and the downstream channel.

In a multi-purpose reservoir with a flood retarding function, the outlet conduit will be sized by the required flood discharge and the requirements of TR-60. A conduit of such a size will not generally be limiting for other purposes, and the regulation for such other purposes will be based on gate hydraulics alone.

Factors that determine the flow in a gated outlet include variables as the size, shape, and type of control gate and conduit; the slope, length, and roughness of the conduit; the inlet and outlet conditions; and the head on the system.

The nomographs and charts in this section were prepared to provide the engineer with the hydraulic relationships commonly encountered in the design of small gated outlets.

The discussion of "Location of Control," "Full Pipe Flow," and "Partial Pipe Flow" is a simplification of actual conditions, in some cases to a point that can be misleading to the unwary.

Many problems are associated with the calculation of water surface profiles in a circular cross-section on a fixed grade line. The major ones are:

(1) The effect of air entrainment and consequent bulking of the flow.

(2) Determination of energy loss for the bulked flow and its variable "n" value,

(3) Effect of pipe joints, elbows, gates, etc.

(4) Geometry of the inlet for both partial and fully open conditions as well as accuracy in evaluating the tailwater elevation,

(5) The certainty that the conduit, on a compressible foundation, is subject to joint rotation and elongation that make the grade line of the conduit indeterminate.

The rest of the hydraulics section should be read keeping in mind that inlet control means partial pipe flow and outlet control means full pipe flow.

II. LOCATION OF CONTROL

Location of the control from the hydraulic standpoint dictates whether the conduit flows full or partly full and thereby establishes the head-discharge relationship. Slope of the pipe and the tailwater level are factors that determine location of the control. The slope may be mild or steep, that is, it may be flatter or steeper than the slope at which a given discharge will just support flow at a critical stage. For either a mild or steep slope, the control may shift from inlet to outlet depending on the head, tailwater, and gate opening.

For partial pipe flow, the control is normally at the inlet where orifice conditions control the discharge. For full pipe flow the control is at the outlet, and the total head on the system is determined by the elevation of the tailwater. In the case of free outfall at the outlet, the tailwater elevation is considered the center of the pipe outlet.

III. FULL PIPE FLOW

Full pipe flow usually occurs in long conduits with a mild or flat slope or where the outlet is submerged. The depth of water at the entrance must be greater than 1.2 times the inside diameter of the pipe to produce full pipe flow. Partial pipe flow may occur with the inlet submerged if the slope is steep or if the pipe is short enough so that a hydraulic jump does not occur in the length of the pipe and air is admitted through the outlet or by means of a vent. Full pipe flow conditions control for nearly all gate openings if the conduit is on a mild slope.

IV. PARTIAL PIPE FLOW

Partial pipe flow usually occurs in short conduits with sharp corners or inward projecting entrance and low heads. Partial pipe flow may also occur where the conduit is on a steep slope with partial gate openings and free outfall. In this case the inlet acts as an orifice to control the flow.

The inlet must be vented to have orifice control. The vent may be a vent-pipe or the airspace maintained above the water surface during partial pipe flow with free outfall and air admitted from the outlet.

If the conduit flows full at any point and the inlet is not vented, the high velocity flow will carry away entrapped air. The pressure in the pipe can then drop below atmospheric pressure and cause operation problems and structural damage.

V. CAVITATION

Localized constrictions, surface irregularities, and abrupt changes in alignment provide conditions for potential structural damage. This damage is caused by the successive formation and collapse of vapor pockets in low pressure areas associated with high velocity flow. The collapse of vapor pockets cause implosions that result in pitting of the concrete or the metal conduit surface. The pitting then accelerates the effect of cavitation by intensifying the negative pressures.

Several measures will reduce the potential for cavitation: streamlining of entrances and slots; increasing the cross-sectional area; or, introducing air by venting to the low pressure area.

Venting the conduit just downstream of the gate is recommended. Further discussion of vent pipes is presented in Section C, Inlets.

Conduits carrying flow with velocities in excess of 25 fps should be studied for cavitation potential.

VI. USE OF CHARTS AND GRAPHS

It should be recognized that these charts and graphs were developed for given conditions. Some of the relationships were derived from model studies. The curves or values may be an average of the results of these studies. Any deviation from the condition of the study could change the results; however, these relationships will give usable answers for most design problems in small gated outlets. If exact values are required for a specific structure, detailed computations will be necessary to evaluate the exact conditions and requirements for that structure.

A. Full Pipe Flow With Gate Fully Open

1. Figures B-1 through B-4

Figures B-1 through B-4 were developed to quickly determine the pipe size and flow velocity for a given height of dam and discharge. THESE CHARTS APPLY TO FULL RESERVOIR CONDITIONS. For lower stages, chart discharges will be high and Figures B-6 through B-10 should be used. Each chart gives the relationships for a different conduit roughness (Manning's "n" value). They apply for an entrance condition of a fully open gate with square corners and a single miter bend. Energy loss is based on a pipe length for an embankment slope of 3:1 upstream and 2:1 downstream. The top width of the embankment is $2\sqrt{H+5}$ where H is the vertical distance from the spillway crest to gate centerline. A combined headloss coefficient of 1.24 was used for the entrance and elbow. The losses for these conditions are considered to be average for small dams with the head range shown on the charts.

The charts are entered with known values of head and discharge. The pipe diameter and velocity of flow are determined from the curves. If the point falls between two diameter lines, the larger diameter must be used to obtain the given discharge and velocity can be determined directly.

The most common pipe sizes for concrete and corrugated metal pipe were used in the construction of these charts. Relationships for other pipe sizes may be determined by interpolation.

2. Figures B-5 through B-10

Figures B-5 through B-10 give the relationships for full pipe flow with various entrance conditions and variable pipe lengths. THEY ARE FOR USE IN HYDRAULIC ANALYSIS WHERE THE RESERVOIR IS LESS THAN FULL OR WHERE THE PIPELINE EXTENDS BEYOND THE TOE OF THE DAM. They are also valid for the full reservoir stage although additional computation is required to find flow velocity. Figure B-5 is used to determine the loss coefficient (K_e) for various entrance types. Figures B-6 through B-10

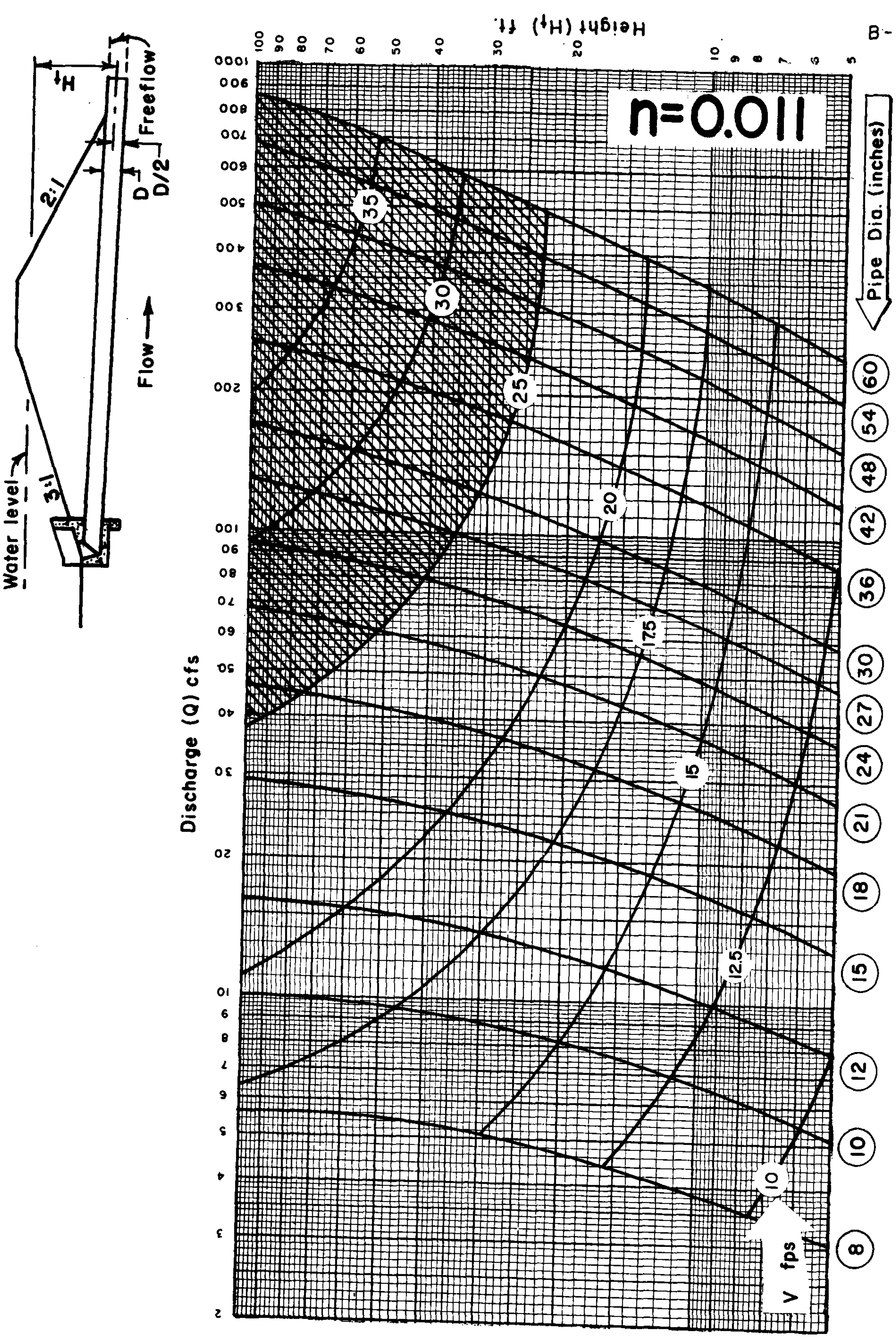


FIGURE B-1
FULL PIPE FLOW STAGE DISCHARGE
EWP Unit Portland, Oregon

Revised 6-82

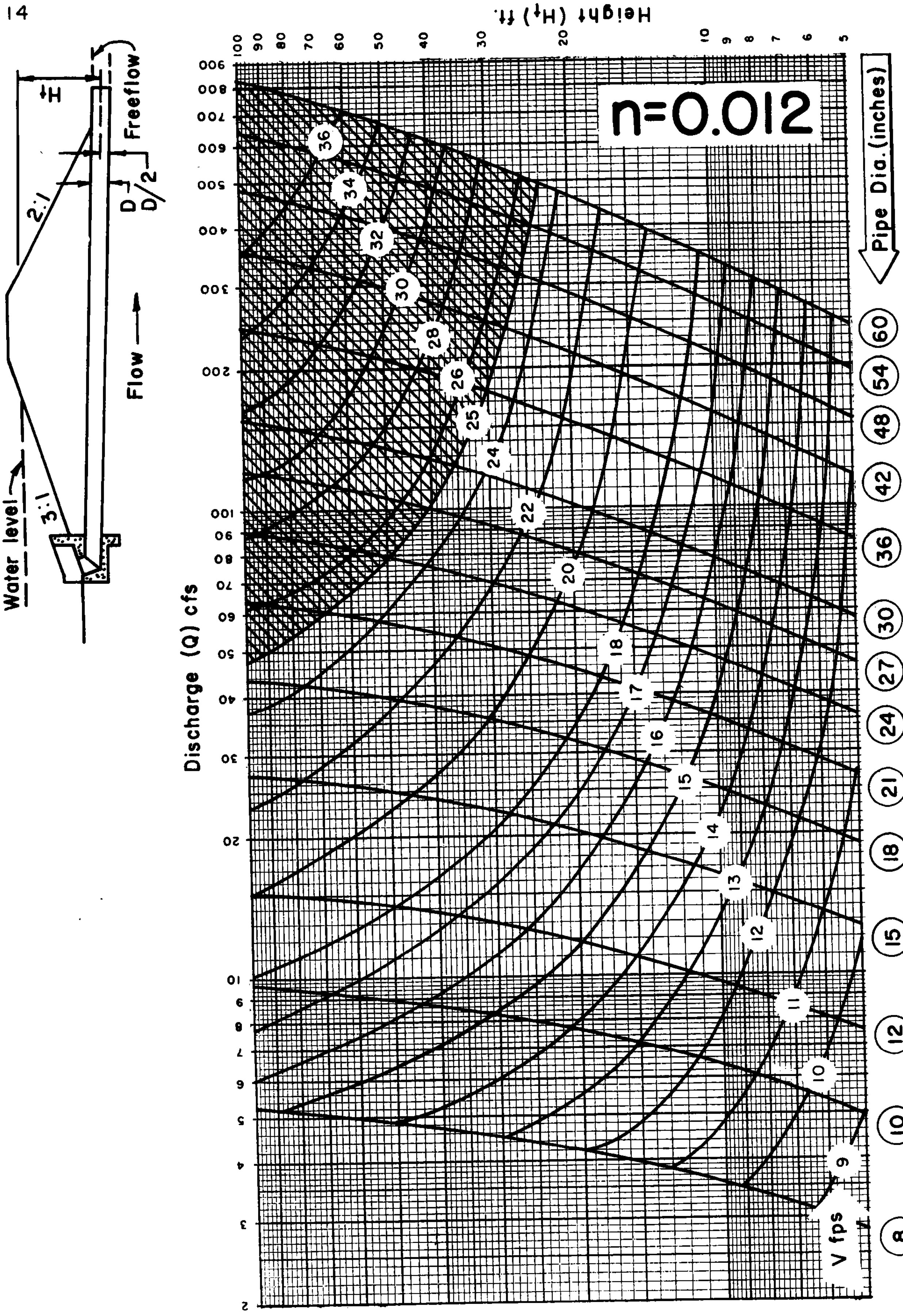


FIGURE B-2
FULL PIPE FLOW
STAGE DISCHARGE
EWP Unit Portland, Oregon

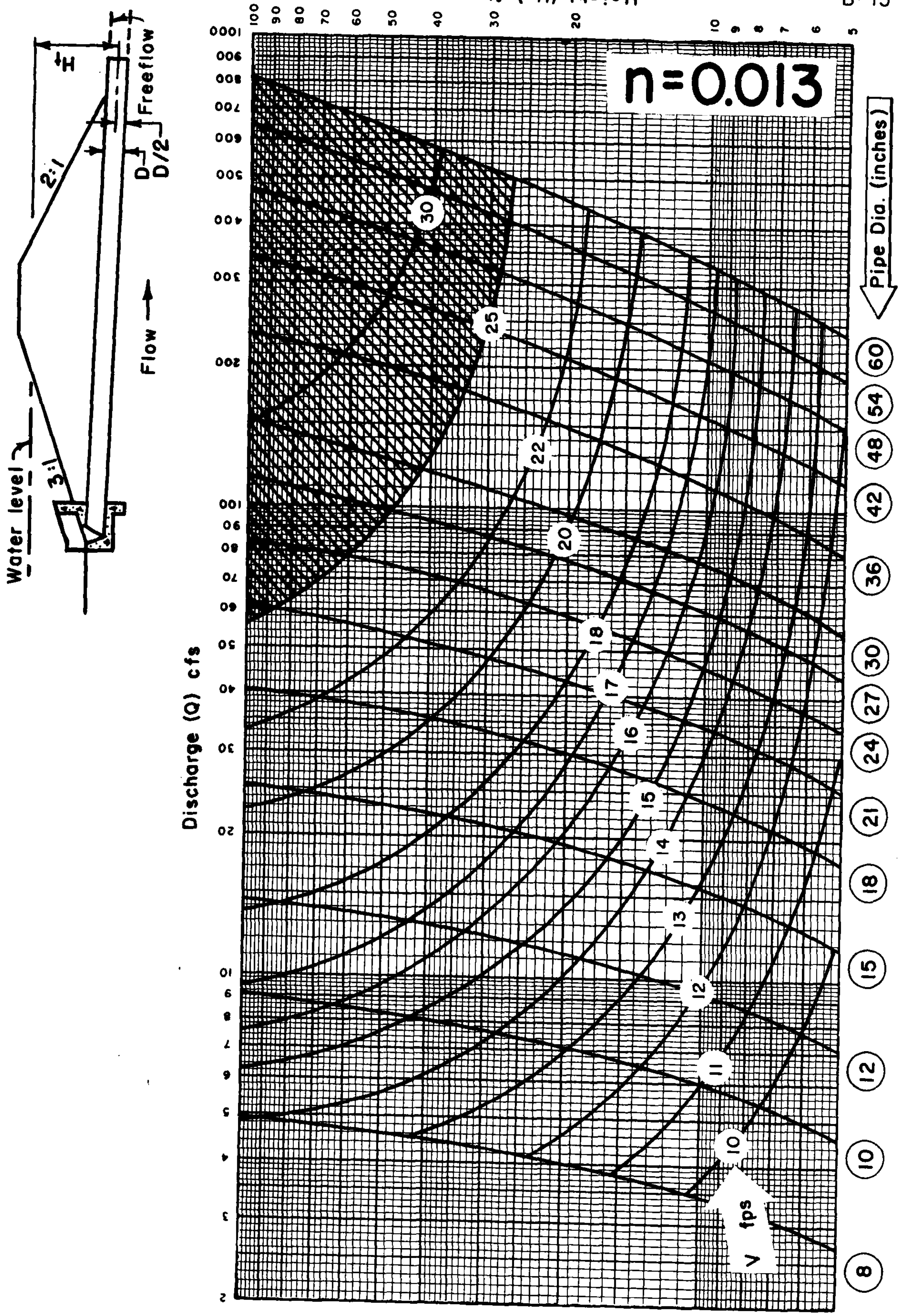


FIGURE B-3
FULL PIPE FLOW
STAGE DISCHARGE
EWP Unit Portland, Oregon

Revised 6-82

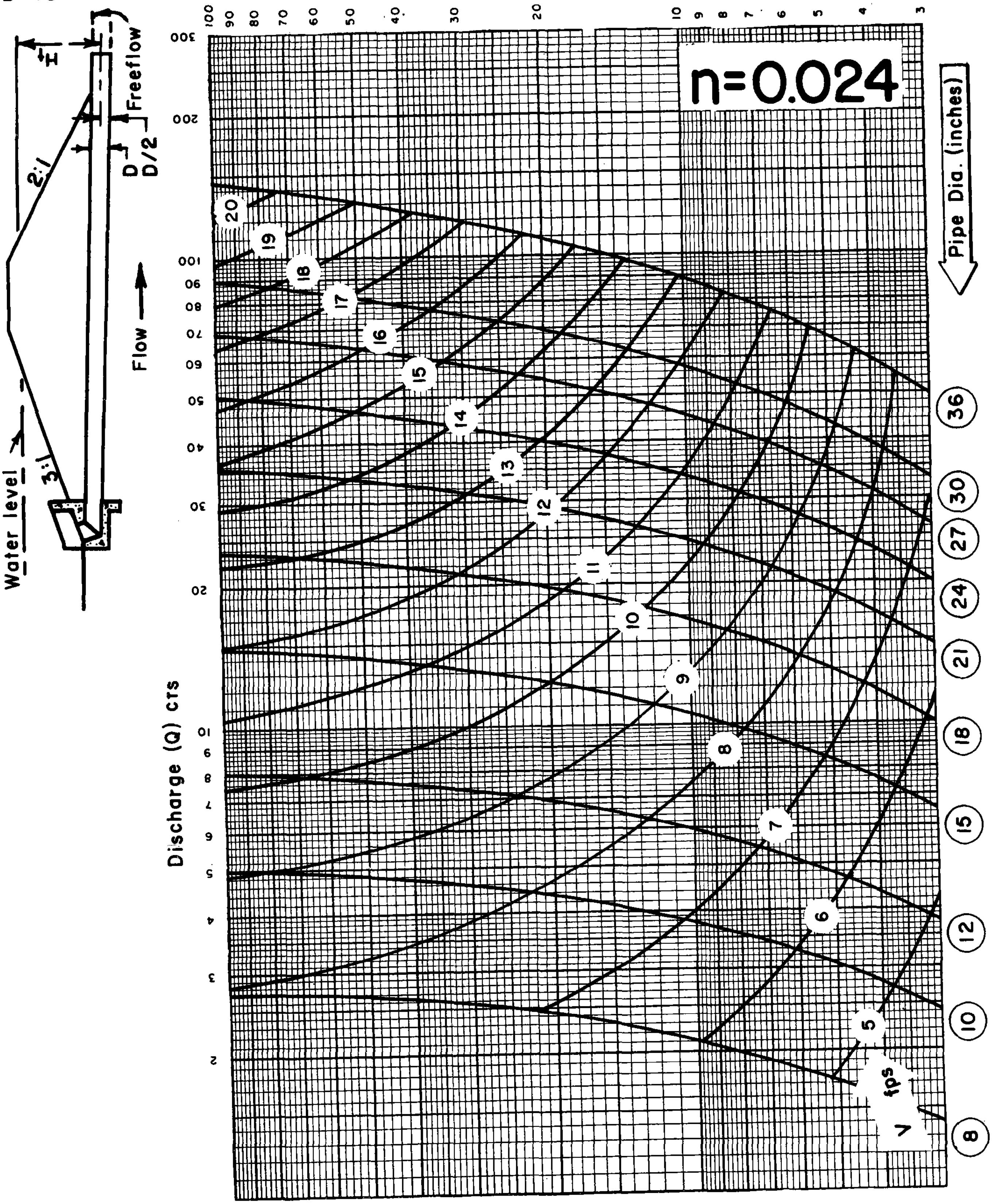


FIGURE B-4
FULL PIPE FLOW
STAGE DISCHARGE

EWP Unit Portland, Oregon

SECTION C - INLET STRUCTURES

1. INTRODUCTION

Innumerable varieties of inlet structures are designed individually for essentially the same conditions and requirements. The standard structure in this section has evolved over a period of years and incorporates details based on experience gained from a number of installations. This structure is for use with a 3:1 upstream embankment slope.

Two trash rack systems are shown: one for low head designed as a complete unit, and one for higher heads built in sections that can be handled for maintenance without heavy lifting equipment. If fish are to be retained in the reservoir, special design is necessary that considers fish types, inlet depths, and flow velocities near the inlet.

A single-miter elbow has been selected in preference to a multiple miter. Savings in head due to the improved hydraulics of the latter does not justify the additional cost of fabrication.

II. GENERAL CRITERIA

The standard inlet was designed using Class 3000 concrete with an allowable stress of 0.45 f'_c. If Class 4000 concrete is to be used, no change in detail is necessary other than to specify the higher-strength concrete. Intermediate grade steel is used with a yield stress of f_y = 40,000 psi.

Reference is made to the following specifications (not included in this manual) as they affect the gate details:

a. Construction Specification Nos. 71, 81.
b. Materials Specification Nos. 553, 571, 572, 573, 581 and 582.

III. NOMENCLATURE AND GENERAL NOTES

The common gate, frame, and lift devices are illustrated on Figure C-1. Rising stems have been most common in SCS installations, connecting the gate slide to the hand wheel or geared lift. Non-rising stems can be used for special conditions of limited headroom or broken alignment, where the stem is used to transmit only torque, and not any axial force.

Of the four types of gate seat backs, the one most used in the Service is the spigot back. It is cast directly in the concrete or grouted into place, and anchored by preset bolts. It may also be connected directly to steel pipe. The spigot back is limited in availability to the low and medium duty gate. Not all manufacturers supply this type.

The flange back gate resists warping better than the spigot back. It is used to advantage in mounting on existing walls. For larger, heavy duty gates, this type is used with a thimble previously cast in the receiving wall.

The flange and spigot back is used primarily where top and bottom wedges are required and the gate frame is cast directly in a concrete structure.

The flat back gate should be used with a thimble. A thin coat of mastic or fibrated asphalt should be placed between the contact surfaces.

The gate seat opening may vary with class of gate. For light duty the gate seat opening may be circular. For heavier duty gates the seat may have a rectangular opening but the gate frame will reduce to a circular opening. A rectangular opening is used with special seat facings (usually bronze).

Bronze seat facings are recommended even with light duty gates. At the time of final adjustment a light application of waterproof grease should be applied to the seat faces.

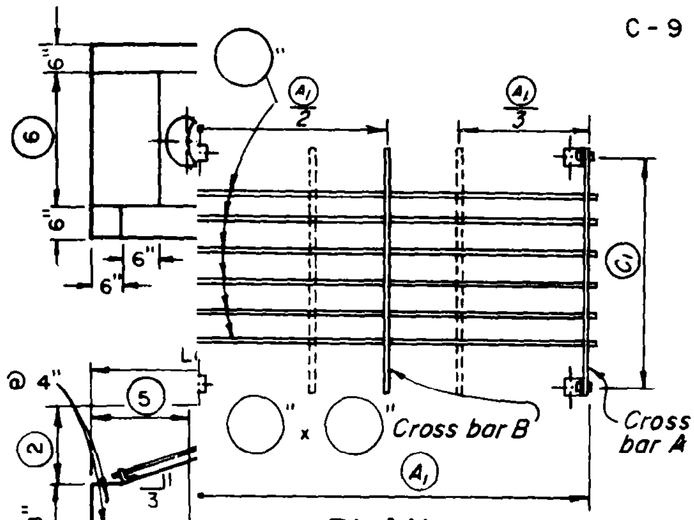
Some leakage can be expected: the maximum should not exceed 0.2 gpm per foot of periphery at a face pressure equal to 16 ft of water.

IV. STANDARD INLET

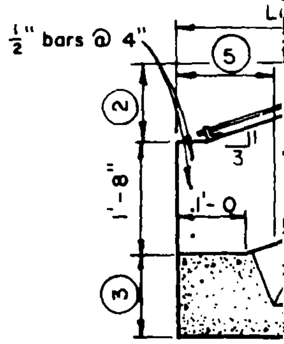
A. Structure Size

Dimensions of the standardized inlet are tabulated on Figure C-2. The size of the inlet is directly related to the conduit diameter and is the same regardless of the head. Dimension (4) will require adjustment when pipe diameters other than those listed in the tabulation are used. This adjustment is required to keep the rest of the dimensions constant for each structure size. Structure dimensions pertain to an embankment slope of 3:1. A typical standard drawing (size H - 21" conduit) is shown on Figure H-3 of the completed example.

Inlet structure size J (36" conduit) will require change if hydraulic controls are used with the cylinder mounted at the gate. Discussion of controls will be found in Section D.



PLAN



ote:
When one intermediate bar is used
)lace at center.
When two intermediate bars are used
space at A/3.

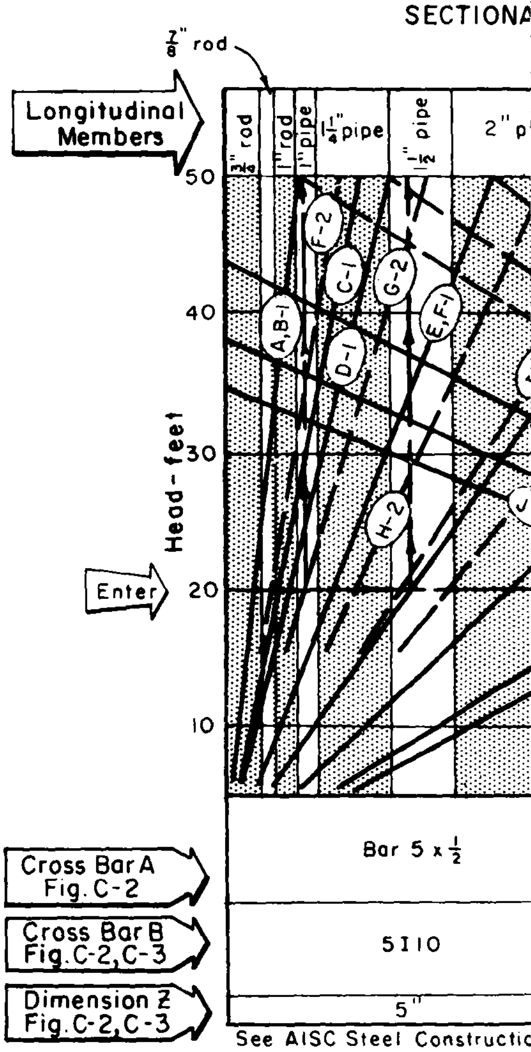
JRE DIMENSIONS					
	F	G	H	I	J
"	18"	20"	24"	30"	36"
"	9"	8"	1'-0"	9"	6"
"	1'-8"	2'-0"	2'-6"	2'-10"	3'-0"
"	1'-11"	1'-11"	2'-5"	2'-5"	2'-11"
"	2'-10"	3'-0"	3'-8"	3'-6"	3'-8"
"	2'-0"	2'-2"	2'-2"	2'-4"	2'-10"
'	3'-0"	3'-0"	4'-0"	4'-0"	4'-0"
	5'-6"	6'-6"	8'-0"	9'-0"	9'-6"
"	5'-0¼"	6'-1"	7'-7¾"	8'-8½"	9'-2¾"
	3'-9"	3'-9"	4'-9"	4'-9"	4'-9"
	3'-6"	3'-6"	4'-6"	4'-6"	4'-6"
:	9"c-c	10"c-c	10"c-c	12"c-c	12"c-c
	2.91	3.40	4.72	6.52	7.00
	172#	201#	298#	323#	354#
) 2 sheets per each structure size					

SECTIONA

ble J-C1 for volumes using other types

dimension 4 to keep the total height of

use with a flange back gate.



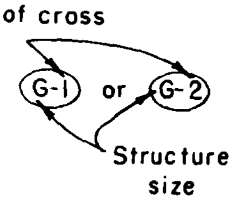
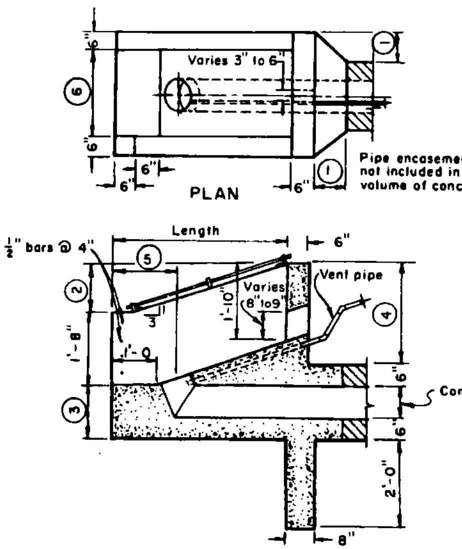
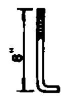


FIGURE C-2

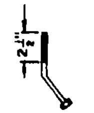
INLET STRUCTURE

EWP Unit Portland, Oregon

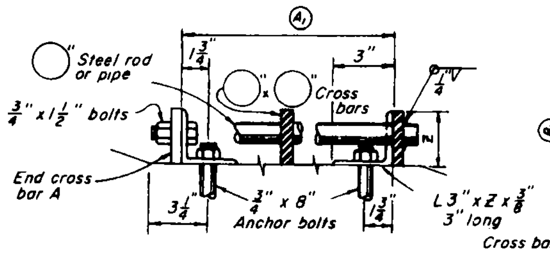




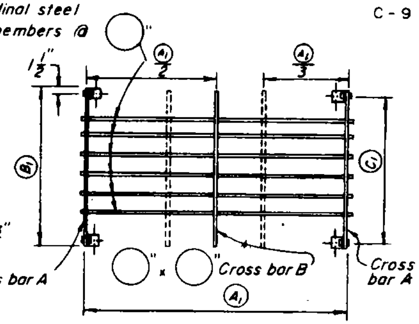
ANCHOR BOLT



ALT. ANCHOR BOLT



DETAILS



PLAN

TRASH RACK

Not to Scale

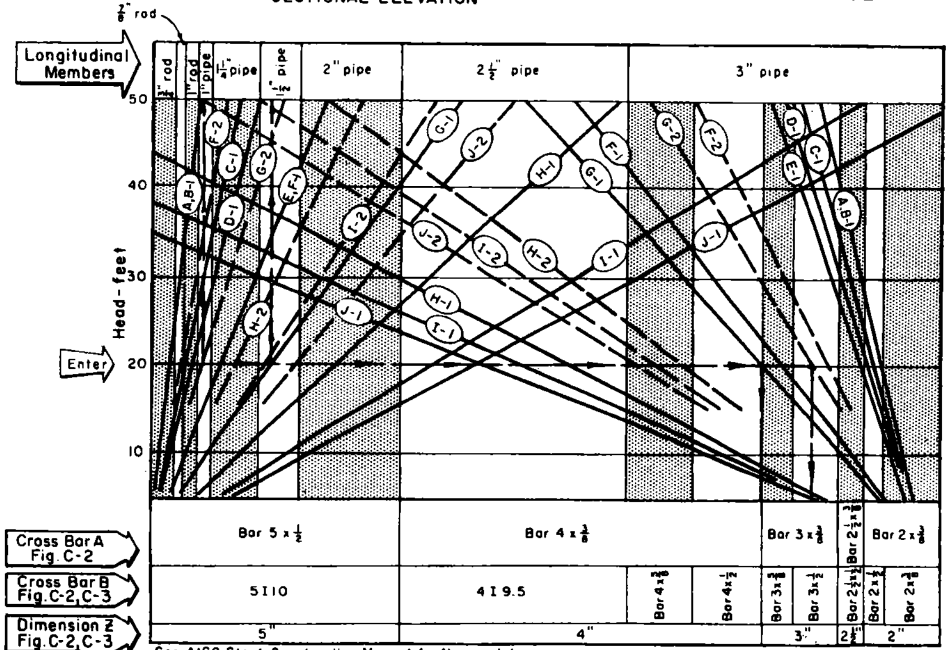
Note:
When one intermediate bar is used place at center.
When two intermediate bars are used space at $\frac{A_1}{3}$.

Structure / Conduit Size / ITEM	A	B	C	D	E	F	G	H	I	J
	8"	10"	12"	14"	16"	18"	20"	24"	30"	36"
1	8"	7"	6"	5"	4"	9"	8"	1'-0"	9"	6"
2	1'-2"	1'-2"	1'-4"	1'-6"	1'-8"	1'-8"	2'-0"	2'-6"	2'-10"	3'-0"
3	1'-1"	1'-1"	1'-5"	1'-7"	1'-7"	1'-11"	1'-11"	2'-5"	2'-5"	2'-11"
† 4 (Varies)	2'-4"	2'-2"	2'-6"	2'-8"	2'-8"	2'-10"	3'-0"	3'-8"	3'-6"	3'-8"
5	1'-6"	1'-7"	1'-9"	1'-10"	2'-0"	2'-0"	2'-2"	2'-2"	2'-4"	2'-10"
Δ 6	2'-0"	2'-0"	2'-0"	2'-0"	2'-0"	3'-0"	3'-0"	4'-0"	4'-0"	4'-0"
LENGTH	4'-0"	4'-0"	4'-6"	5'-0"	5'-6"	5'-6"	6'-6"	8'-0"	9'-0"	9'-6"
TRASH RACK A_1	3'-5¼"	3'-5¼"	3'-11½"	4'-6"	5'-0¼"	5'-0¼"	6'-1"	7'-7¾"	8'-8½"	9'-2¾"
TRASH RACK B_1	2'-9"	2'-9"	2'-9"	2'-9"	2'-9"	3'-9"	3'-9"	4'-9"	4'-9"	4'-9"
TRASH RACK C_1	2'-6"	2'-6"	2'-6"	2'-6"	2'-6"	3'-6"	3'-6"	4'-6"	4'-6"	4'-6"
TRASH RACK BAR SPACING	4"c-c	4"c-c	6"c-c	6"c-c	8"c-c	9"c-c	10"c-c	10"c-c	12"c-c	12"c-c
⊛ VOL. CONC. C.Y.	1.33	1.32	1.57	1.84	1.97	2.91	3.40	4.72	6.52	7.00
REIN. STEEL	109#	103#	122#	136#	139#	172#	201#	298#	323#	354#
STD. DWG. NO.	7-N-20465 (Suffixed by size letter) 2 sheets per each structure size									

⊛ Volume of concrete using C.M.P. or steel pipe. See Table J-C1 for volumes using other types and sizes of pipe.

† If pipe diameter is different from that tabulated adjust dimension (4) to keep the total height of the inlet constant. (See discussion Section C-IV-A)

Δ Add 8" each side and below gate opening for use with a flange back gate.



See AISC Steel Construction Manual for Nomenclature

Revised 6-82

Example

Given: Structure size G
Head = 20 feet

Find: With one intermediate cross bar use line (G-1)
Longitudinal member = 1½" pipe
Cross bar A = 4" x ⅜", Cross bar B = 4" x ½"
Z = 4"

With two intermediate cross bars use line (G-2)
Longitudinal member = 1" pipe
Cross bar A = 3" x ⅜", Two cross bars B = 3" x ½"
Z = 3"

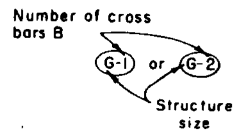


FIGURE C-2

INLET STRUCTURE

EWP Unit Portland, Oregon

Contents (continued)

Figures

Figures (continued)

SECTION D - CONTROLS

I. INTRODUCTION

Water storage reservoirs require outflow control to satisfy downstream water needs. The control system should be adjustable to a degree that waste is minimized, and should be able to retain its setting.

The most common method of reservoir water control is the slide gate operated by means of a handwheel or geared crank lift. Support for the lift and the stem is provided by concrete pedestals set in the embankment.

The hydraulic cylinder has been used a long time for slide gate control in water treatment plants. Recent advances in materials and production technology made the hydraulic system adaptable to many applications in earth dams.

Cylinders are available from many manufacturers which are built in several mounting styles to the uniform mounting dimensions of the Joint Industry Conference (JIC), National Fluid Power Association (NFPA), and the American National Standards Institute (ANSI). The interchangeable series has other standard and optional features such as easily replaceable rod seal glands, bleed ports, "zero" leak seals, and stainless steel piston rods, which are highly desirable for the special requirements of SCS installations.

II. DESCRIPTION OF THE SYSTEMS

A. Mechanical

The mechanical system develops its lifting force from the principal of the screw. A handwheel or gear reduction unit, see Figure C-1, converts the effort of the operator on the handle to torque on the lift nut and thrust on the stem and the gate slide. The reaction to this thrust is taken by the mass of the gate lift pedestal and the embankment in which it is embedded.

The thrust is transmitted to the gate by the stem, held in alignment by guides that are in turn secured to gate stem pedestals set in the embankment. If the basic structure is all concrete, the lift, guides, and gate frame are secured to it and all reactions are transmitted through it. Some manufacturers list a single maximum guide spacing for each stem size. The spacings shown on Figure D-1 are set by the allowable combined stresses in the stem material caused by the axial loading and bending from stem weight and eccentricity. Guides have several inches of vertical adjustment for correcting stem alignment as the embankment settles. Provisions for lateral adjustment are also included.

A variation of this system, the non-rising stem model is illustrated in Figure C-1, in which the lift nut is mounted in the gate slide and moves up or down as the stem is turned at the control station. Thrust is taken by a bearing on the gate frame yoke and the length of stem from the control station to the frame transmits torque only. In this variation the handwheel or gear unit is keyed to the stem.

In areas where freezing is a regular winter occurrence, it is necessary to encase the stem and bury it to avoid its being bound in ice or forced out of alignment. The encasement consists of a pipe filled with oil, equipped with seals at each end to allow the stem to slide freely through while retaining the oil. Carbon steel stem is used throughout the encasement length except those portions which move through the seals. To maintain an effective seal, the section of stem that moves through the seal must remain corrosion-free and smooth, and is made of bronze* or stainless steel. Even though tables indicate that a smaller stem of stainless steel could replace the regular size of carbon steel, it is not practical (considering the necessary adaptions) to change the size for one section of the stem.

If it is necessary to use a bolted splice instead of the riveted one shown in the standard drawing, it will also be necessary to increase the size of encasement pipe and the quantity of oil.

In some cases, a "T" has been used in the encasement near the weather seal for addition of oil. This detail has not been shown on the standard drawing since the weather seal can be loosened for the infrequent need for more oil.

There are instances where the upper end of a stem encasement has been cast into the concrete of the lift pedestal. Designs in this Section consider that no thrust is to be carried in the encasement pipe. The supporting angle at the lift pedestal serves only to aid alignment and to relieve the packing gland of supporting the encasement weight. Any repair to lift, stem or gate that will require the disassembly of the encasement will show the advantage of independent construction.

B. Hydraulic

The muscle of the hydraulic system is the double-acting hydraulic cylinder that uses oil under pressure (up to 3000 psi) to move the piston and the attached gate slide. Pressure is developed by a hand or power-operated pump at the

* High cost of bronze makes stainless a more economical choice.

control station and directed through piping to the opening or closing end of the cylinder by a 4-way valve. Typical Hydraulic Control Applications, Figure D-20, show variations in gate orientation that can be obtained without the usual alignment and access problems. The control station can be placed at any convenient location within economic limits. Components are:

1. Cylinder

   As stated earlier, a cylinder selected from the JIC Interchangeable Series can be supplied by several manufacturers. Certain options are necessary to meet the special needs of Service installations. Stainless steel piston rods are essential for submerged location. The exterior surfaces of the cylinder should have corrosion protection of chrome, cadmium plating or an epoxy enamel.

   Packings for the piston and the rod gland must have maximum sealing characteristics to enable the piston to hold the gate in a raised position over a period of several days. A multiple-v type seal or a new cup type with an O-ring filler will give near zero leakage. The rod gland of these cylinders is replaceable without disassembling the whole cylinder.

2. Pump

   Pressure to operate the cylinder is developed by a pump powered by hand, electric motor, or internal-combustion engine. There are several variations of pumps available that meet the minimum requirement for pressure. Hand pumps may be single or double acting, with dual pistons, adjustable leverage arrangements, or self-regulating devices to vary the flow rate when pressure requirements change. Rotary pumps for powered operation are usually of the gear, vane, or axial-piston type, listed in the ascending order of pressure capability.

3. Reservoir

   An oil reservoir is necessary and should be located to keep the pump intake full at all times. Minimum reservoir capacity should be sufficient to contain the oil displaced by the cylinder piston rod when in the retracted (upper) position.

4. Control Valve

   A 4-way valve directs the flow of oil from the pump to the opening or closing side of the cylinder piston and allows return flow of oil to the reservoir. This valve may be a rotary or a spool type, either one further qualified as closed or tandem center.

A rotary-type selector valve effectively stops any back flow from the cylinder while in a neutral position, and maintains the set position of the gate.

The spool-type valve, commonly used on hydraulic equipment, has internal leakage inherent with its design and can allow the gate to creep closed over a period of time unless supplemented by a pilot-operated check valve at the cylinder.

For hand-operated pump installations, a closed center valve is recommended. It will permit no through flow when the valve is in a neutral position.

For power-operated systems, a tandem center valve is necessary to permit free return flow to the reservoir when the pump is idling.

5. Hydraulic Lines

Pipe lines connecting the control station and the cylinder at the gate should be either stainless steel tubing or a reinforced synthetic hose suitable for medium or high pressure. In most cases they will be buried in the face of the embankment within a conduit of galvanized, fiber or plastic pipe for external protection. Hose fittings should be corrosion resistant and of the permanent type. Hose in long (to 250 ft) lengths reduces the number of joints and the opportunity for leakage, and simplifies installation. Figure D-25 contains data helpful for selection.

6. Hydraulic Fluid

The hydraulic fluid is most commonly a mineral base oil with additives to maintain chemical stability, lubricity, and anti-corrosion characteristics. Its viscosity should not exceed 3000 SSU (Saybolt second units) at the lowest expected operating temperature. This is to assure oil flow to the pump, lubrication, and reasonable level of friction affecting operating effort.

III. COMPARISON

A choice between mechanical and hydraulic controls can be made by evaluating the advantages of the conditions for each system. For the usual situation, costs have been compared and the black dashed line on Figure D-1 represents the combination of head and gate size for which costs are about equal. Cost studies favor the mechanical system below the line and hydraulic above. The cost comparison assumes no stem is used in the hydraulic system and the cylinder is located at the gate.

The advantages and disadvantages of the two control systems to be evaluated for a particular installation are:

A. <u>Mechanical System</u>

1. Advantages

Simplicity of design. Economy in many sizes of gate-frame-lift units. Gates, lifts, and accessories are available from the same manufacturer. This factor is of more importance when it is necessary to place some responsibility for design with a subcontractor or supplier. Positive indication of the gate opening can be obtained. Portable gasoline or electric drives are available.

2. Disadvantages

The system needs careful alignment of all components. It is subject to misalignment with any settlement of the embankment. Broken slopes need special equipment, such as universal joints. Installations on vertical risers need access facilities such as catwalk or boat. Stop nuts are the only safety devices on standard units. Excess force on the handwheel or crank can damage the gate or the structure. Powered and automatic units with all safety devices are quite expensive. Labor efficiency is about 20%.

B. <u>Hydraulic System</u>

1. Advantages

The gate may be oriented in any position without alignment with the control station. Broken slopes are no problem. The control station can be located anywhere (such as at the downstream measuring device) that can be reached with flexible conduit; convenience can be balanced with economy. Controls are easily adapted to power, remote, and automatic control. A multiple gate installation can be placed more compactly to use a common pump and power source. This system has an economic advantage in many slope installations or on risers that would otherwise require access facilities. Safety devices are easily incorporated into this system. Parts and service are available from local distributors. Labor efficiency is about 70%.

2. Disadvantages

   There is a possibility of oil leakage. Positive indication of the gate opening is difficult. An approximation can be made with an oil level sight gage on the reservoir. Low temperatures can affect the speed of operation. Figure D22b shows alternative systems with reserve for line failure.

C. Labor Requirement

As a means of explaining and illustrating some of the principles involved in labor appraisal, the following example and explanation has been included.

Given: A 30" x 30" gate under 40' differential head.

Determine: Work required to open the gate by mechanical or hydraulic lift.

Solution:

The force required to move the gate is given by equation

$$F = fwhA + G$$

where:

- F = total force required at the gate (lbs)
- f = coefficient of static friction between gate slide and seat
- w = density of water (62.4 lb/cu ft)
- h = unbalanced head of water on center of gate (ft)
- A = area of gate, including 1 inch seats (sq ft)
- G = weight of gate slide in air (lbs)

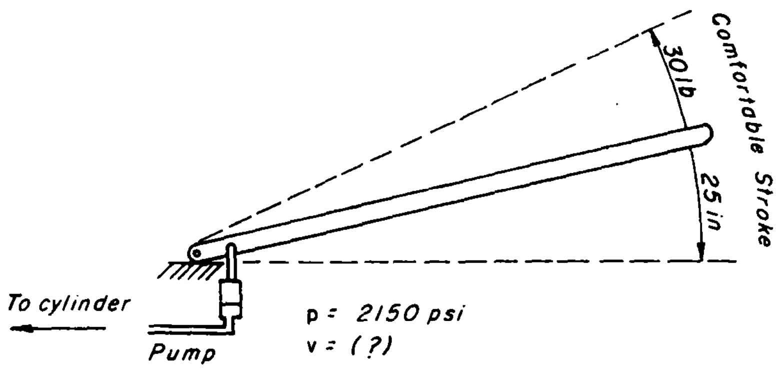
For a mechanical lift one manufacturer recommends a value of f = 0.3 for operation (relying on a momentary overload to overcome static friction, f = 0.7). The average weight of a 30" x 30" gate is 450 lbs.

Substituting

$$F = 0.3\ (62.5)(40)(2.67)^2 + 450 = 5790 \text{ lbs}$$

The manufacturer's selection is a geared crank lift with a 4 to 1 ratio and a stem diameter of 2 inches. The rating of the lift lists a capacity of 7540 lbs with 25 lb force on the crank, and 16 turns required per inch of gate movement. Efficiency of the lift is included in this catalogue rating.

If a comfortable stroke is assumed at 30 pounds through 25 inches, the useful piston displacement will be found by reversing the above process.



Hydraulic Equivalent
for reasonable input

$$v = \frac{W_1}{p} = \frac{FD}{p}$$

$$v = \frac{30 \text{ lb} \times 25 \text{ in}}{2150 \ \frac{\text{lb}}{\text{in}^2}}$$

$$= \frac{750}{2150} \text{ in}^3$$

$$= 0.349 \text{ in}^3$$

where W_1 = force applied X distance (per stroke)

The number of strokes required to move the gate one inch is:

$$n = \frac{A}{v}$$

$$= \frac{6.811 \text{ in}^3/\text{in}}{.349 \text{ in}^3}$$

$$= \frac{19.5 \text{ strokes}}{\text{inch}}$$

n = number of pump handle strokes
A = piston area or volume per inch of cylinder piston movement
v = useful pump piston displacement

The work applied in moving the gate one inch

$$
\begin{aligned}
W &= nW_l \\
&= 19.5 \times 750 \text{ in-lb} \\
&= 14{,}600 \text{ in-lb}
\end{aligned}
$$

For the example the mechanical lift requires 28,700 in-lb of work input to accomplish 5,790 in-lb of work output. The efficiency is the ratio.

$$
\begin{aligned}
\text{Eff} &= \frac{\text{work output}}{\text{work input}} \times 100 \\
&= \frac{5{,}790 \text{ in-lb}}{28{,}700 \text{ in-lb}} \times 100 \\
&= 20\%
\end{aligned}
$$

As calculated, considering losses due to oil flow, the hydraulic system requires 14,600 in-lb of work to accomplish 12,930 in-lb of work. Output efficiency for this part of the system is

$$
\begin{aligned}
\text{Eff} &= \frac{12{,}930 \text{ in-lb}}{14{,}600 \text{ in-lb}} \times 100 \\
&= 88\%
\end{aligned}
$$

The efficiency of a cylinder is about 95-98% and the pump is estimated at 85% based on a larger ratio of friction surfaces and more mechanical linkage.

The overall efficiency of the system is a product of these three, or

$$
\begin{aligned}
\text{Eff} &= 0.88 \times 0.95 \times 0.85 \times 100 \\
&= 71\%
\end{aligned}
$$

From the above there is considerable difference in labor between the two systems which will become even greater if the friction factors should be considered more nearly equal. The difference becomes significant when costs are assigned to the labor of operation

D. Motor Operated Controls

Power drive equipment should include the following features:

Reverse - for opening or closing the gate.

Clutch - for quick disengage especially in electric motors of portable units.

Torque limit - prevents overload when gate is seated or hits a submerged object.

Adapter - connects drive unit to lift control.

Gear reduction - proper reduction of motor speed to recommended gate shaft revolution thru the lift control device.

Drive equipment may be portable and serve several gates or may be permanently installed and suitable for outdoor operation of a single gate, as is necessary in automatic operation.

The drive equipment may be gas engine, electric, or a gas engine operated generator for an electric motor.

Manual control size and gear ratio are selected not to exceed man's capacity to turn a crank. The need for a motor to operate the controls will depend primarily on the allowable time limit for resetting the gate. Small gates would normally not require power operation. The larger gates could require motorized lifts if the gate is to be moved over its full height; however, seldom will the gate be fully opened or closed against a full head at any one time. A typical irrigation season might begin with 1/2 of the design flow, requiring 1/4 opening of the gate with a full reservoir. Flow changes throughout the season require minor adjustments of the gate. At 3/4 way through the season, full flow might be obtained with 3/8 gate opening and about 1/2 of full head. For emergency gate closure probably not more than 1/4 to 1/3 of the effort required to move the gate for its entire diameter at full reservoir will be needed.

E. Power vs Manual Control Operation

Figure D-24 has been developed for calculating effort required to operate the controls. In this figure, present day manpower capability has been assessed in terms of fractional horsepower. Entering with the required force in the appropriate system (hydraulic or mechanical) move to the intersection with the desired gate travel, follow the 45° guide line down to the point of intersection for the limiting time for operation, move horizontally to read horsepower and intensity of physical effort.

IV. GATE CONTROL SELECTION PROCEDURE

Once the gate size has been determined, the selection of the gate controls is complicated and yet fairly simple. Part of the complication lies in the variety of catalogue equipment and engineering data available from the several suppliers in the area. Reducing the number of component choices to those available from several suppliers and standardizing the appurtenances simplifies the selection procedure.

The vertical scale at the left edge of Figure D-1 will normally be the maximum head on the gate. Even with an extended pipeline on a steep slope very little additional head will be developed below the gate provided the system is vented as recommended in Figure C-5. Except for unusual situations the head on the system is measured from gate centerline to free water surface.

Two horizontal scales immediately below the body of the chart list the additional information normally required before the system can be designed. Emphasis must be placed on the fact that while the conduit size and gate size may be the same, the load is exerted over a greater area because of the gate seats. Adding 3 inches to the gate diameter will be sufficient for most gate models to allow for the extra area over which the water pressure can be applied. A word of caution: A CIRCULAR CONDUIT MAY HAVE A GATE WITH SEAT FACINGS SET IN A RECTANGULAR PATTERN THAT MATERIALLY INCREASES THE LOAD ON THE CONTROL SYSTEM. In this case, a rectangular area including gate seats should be used in calculating resisting force.

A. <u>Mechanical Controls</u>

The total load to be handled by the components of a gate control system varies with the size of gate and head of water. A series of diagonally curved lines on Figure D-1 expresses the variation of load directly into component size requirements rather than in pounds. Since the stem diameter, the lift and its pedestal are sized for this common load, their selection has been incorporated into this one figure.

1. Lift Pedestal Size

The uppermost scale of Figure D-1 is divided into six zones, A thru F, representing standardized lift pedestal sizes and the range of load (gate size vs head) for which they were developed. Zone limits have been extended into the body of the figure by the solid black diagonally curved lines. Details for the lift pedestal are found on Figures D-9 thru 14 and in the Appendix, Table J-D2.

2. Stem Diameter

The second scale across the top of Figure D-1 is divided into three shaded areas extending into the body of the figure.

Chart 3 is divided into 14 irregular shaped zones defined by the heavy black lines and labeled with a cylinder bore size enclosed in a circle. Beside each bore size is the area of the piston that is effective in the pull or retracting stroke. The abbreviation Std or O.S. following the area indicates whether the piston rod is standard or oversize. Each zone is divided into two areas: the shaded area represents pressures between 2000 and 3000 psi with the higher values at the top of the area; the white area represents pressures below 2000 psi.

A point on Chart 3 for a combination of thrust and distance (L) determines the cylinder requirements: pressure (greater or less than 2000), bore, and rod type (standard or oversize).

4. Reservoir

Minimum reservoir capacity for oil storage is the volume of the cylinder less that displaced by the piston and rod. Displacement of an oversize rod is greater than that for the standard rod. Chart 4 of Figure D-21 takes this in account by providing two vertical scales for a given cylinder bore size. The horizontal scale of Chart 4 is graduated for values of stroke which is the distance the piston must move to open the gate slide to clear the opening, usually gate diameter plus 3 inches. Having determined the cylinder and stroke requirements, an intersection of lines projected from these values will establish a point on Chart 4 from which reservoir capacity can be interpolated. A standard reservoir of this size or larger is required to keep the pump full.

5. Pumps

Every hydraulic gate control system will have a hand pump, alone, or as an auxiliary to a powered unit. The requirement is simple: to develop the required pressure in the cylinder with a reasonable force on the handle. The rate of flow will be dependent on the operator.

The pump for a powered installation will be selected according to pressure requirement of the system, about as follows:

Pressure Required	Pump Type
to 1200-1500 psi	gear
to 2000-2500 psi	vane
to 2000-3000 psi	axial-piston

Electric power is more convenient to control and economical if it is reliable and available close to the installation. A gasoline engine can be adapted to any location. Either type should drive the pump at the proper speed. See Design Details.

6. Valves

A four-way rotary-type selector valve will provide the required control and sealing characteristics for the majority of SCS installations. Port sizes will depend on the tubing to be used. Other choices are concerned with the type of circulation patterns.

For Conditions	
Handpowered system single cylinder	- use closed-center
Powered system single cylinder	- use tandem-center to allow for free oil return to tank
Powered system multiple cylinder	- use closed-center valves with pilot-operated relief valve as by-pass

7. Tubing

The basic requirements of tubing are (1) to contain maximum working pressure, (2) to pass the required flow with reasonable friction loss, and (3) to resist the environmental conditions in which it must be placed. The following are guides for this selection:

For Conditions	
Enclosed - above water	- use carbon steel tubing or
Exposed to weather	- use carbon steel tubing (plated or coated) or
Conduit enclosed (submerged)	- use pressure hose SAE (100R7 or 100R8)
Direct burial (submerged)	- use stainless steel

Refer to manufacturers' catalogs for pressure ratings of tubing or hose in different sizes.

8. Fluid

The hydraulic fluid should be selected on the recommendations of the component manufacturers for the conditions of climate and exposure in the vicinity of the installation.

V. DESIGN DETAILS

A. Mechanical System

Several of the necessary accessories to a mechanical system are described in the following figures and illustrated at such a scale that they may be traced full size or assembled with other selected details for photographic reproduction, as described in Section H.

1. Gate Stem Encasement Selection Chart, Figure D-2

Figure D-2 is of value only where an unencased stem is being given serious consideration. Omitting the encasement results in economy only when the pedestal spacing exceeds some limiting dimension.

Entering Figure D-2 with the unencased stem spacing obtained from Figure D-1 and moving vertically till it intersects the selected stem diameter will provide a rapid answer. An intersection in the unshaded zone indicates an unencased stem is cheaper; in the shaded zone, the encased stem is cheaper.

Approximate costs per foot of stem for either type installation may be taken from this chart. The line forming the boundary between the shaded and unshaded areas pertains to the encased stem. Its intersection with the stem diameter lines approximates the construction cost. For the unencased stem, intersection of the pedestal spacing with the stem diameter regardless of the zone it is in approximates the construction cost.

2. Gate Stem Details, Figures D-3, D-4

Figures D-3 and D-4, Gate Stem Details, pictures the typical installations of encased gate stems and details of splices for both types. D-3 details are used on drawings that are to be reduced for reproduction. D-4 details are of a suitable scale for direct use on drawings to be used full size. The table on D-3 contains dimensions and other values necessary to complete the details in either scale.

3. Gate Stem Pedestal, Figure D-5

Figure D-5, Gate Stem Pedestal, illustrates the recommended pedestal for support of any size gate stem at any spacing. Either of three guides may be used as shown in Figures D-6, D-7 or D-8. As noted on the drawings, riprap should not cover an unencased stem.

4. Gate Stem Guide and Vent Pipe Hanger, Figures D-6, D-7, D-8

Figures D-6, D-7 and D-8, Gate Stem Guide and Vent Pipe Hanger, show three devices for mounting gate stem to pedestals.

D-6 uses standard U-bolts and channel section and requires no welding.

D-7 uses steel bars bent and drilled to support the stem, encasement and vent pipe.

D-8 illustrates a stem guide typical of those supplied by gate manufacturers, usually of cast iron, and available with bronze bushings as an option. This type is designed to fit closely to a gate stem and ordinarily is not intended for use with encasement.

5. Gate Lift Pedestal, Figure D-9

Figure D-9, Gate Lift Pedestals, provide outline dimensions and quantities for the sizes A through E referred from Figure D-1.

Drawings 7-L-20544 (A-E) listed in the table show construction details including reinforcing steel for each size and are included on Figures D-10 thru D-14. On sizes D and E the cranks are oriented to require the least stooping or bending of the operator.

6. Handwheel Bracket and Base Plate, Figures D-15, D-16, D-17

Figure D-15 thru D-17, Handwheel Bracket Base Plate, give detailed dimensions for fabrication of brackets and base plates for mounting lifts on pedestals.

B. <u>Hydraulic System</u>

Some details of installation that differ from a mechanical system are shown in Figures D-22a and D-22b, Typical Details. It is most important to note the relationships of dimensions Eg and Ey to make a secure fastening to the gate slide and to provide adequate clearance for slide and frame in all parts of the operating cycle. Modification of the stem block is needed to permit threading the block to the piston rod without turning the piston in the cylinder or turning the cylinder itself. The wrench flats are located (dimension Eg) so as to be accessible for holding the rod during the entire threading operation.

The simplest installation uses a flange mount cylinder attached to a yoke on the gate frame. This assembly can be fabricated, assembled and tested under shop conditions before field installation. A side foot mount is applicable in many cases but anchor bolts must be located carefully to avoid difficult field adjustments. A steel plate, slotted for the anchor bolts, can serve as an intermediate adjustable mounting on which to bolt this type cylinder. A third method, using the trunnion mount, has built-in flexibility in one plane of movement and can be used to advantage in special situations, (limited head room) as illustrated.

Safety devices for the system itself are suggested in the following order:

1. A pressure gage, marked with the design opening and closing pressures, will be sufficient for a handpowered system and competent operator.

2. Pressure relief valves, set for design opening or closing pressures and placed in the respective side of the circuit, guard against excess pressures applied by unknowing or unauthorized hand operators or an unattended power unit.

For a power installation, additional calculations are required. The power requirement is set by the amount of work and the time allowed.

From the previous example of a 30" x 30" gate, the work for one inch of gate movement was 14,600 inch pounds. Assuming a maximum allowable time for opening of 5 minutes, the power is found in this manner:

$$HP = \frac{\text{Work}}{\text{Time}}$$

$$HP = \frac{(14{,}600 \text{ in-lb})\ (32 \text{ in.})}{(12\ \frac{\text{in}}{\text{ft}})\ (\text{in})\quad (5 \text{ min})\ \frac{(33{,}000 \text{ ft-lb})}{\text{min HP}}}$$

$$= 0.236 \text{ HP}$$

The oil flow requirement of the system for opening the gate is:

$$Vol = \frac{(6.811 \text{ in}^2)\ (32 \text{ in.})}{(5 \text{ min})}$$

$$= 43.6 \text{ cu in. per minute}$$

A typical pump for such an installation will deliver about 1.2 cubic inches of oil per revolution. The required speed of the pump is then:

$$Rev = \frac{(43.6 \text{ in}^3)}{(1.2\ \frac{\text{in}^3}{\text{rev}})}$$

$$= 36.4 \text{ revolutions per minute}$$

An electric motor of 1/4 or 1/3 HP rating should be adequate for this intermittent use. The common motor speed of 1,760 rpm must be reduced to the 36 rpm of the pump by gear, chain or belt drive. Without speed reduction the pump would attempt its full output against the operating pressure of the cylinder resulting in an overload on the power unit.

The remote location of most reservoirs suggests the use of a gasoline engine. The usual procedure for selecting a gasoline engine is to require 50% more power than the load. For the example, however, there are few choices available less than about 2 HP. As with the electric motor, the speed must be reduced to the speed of the pump.

When a hand pump is used as an auxiliary to a powered pump, it must be installed parallel to the powered pump and the discharge line of each guarded by a check valve against backflow induced by the other unit.

Ideally the control station circuitry and the cylinder assembly at the gate should be shop assembled by workmen with hydraulics equipment experience. Both assemblies can then be tested and adjusted under shop conditions. Quick couplers might be used for the final connections reducing much of the

Assume a 24" rectangular gate weighing approximately 200#, average for this type of gate.

a. Enter Figure D-21 with the area enclosed by the gate seats (24 + 3)(24 + 3) = 5.06 ft^2 and H = 20 ft and find the intersection point. From this point move diagonally down to the right along the 45^{o} grid to about 200# gate weight. Move horizontally from this point to find 4700# thrust.

b. The required stroke is 24 + 4 = 28". Using a front end cylinder mount the unsupported rod length, L. is 28" plus extra length required by the gate slide & frame. This extra distance according to the catalogues reviewed is about 1/4 the gate size. Therefore, using 6" plus 2" for clearance at the cylinder support the total unsupported rod length is then 28 + 6 + 2 = 36".

c. Enter Figure D-21, Chart 3 with thrust = 4700 lbs and L = 36" and find a 2" bore with an oversize rod. Also find operating pressure in the 2000 to 3000 psi zone.

d. Enter Figure D-21, Chart 4 using the 28" stroke and a 2" cylinder bore size with an oversized rod and find the required reservoir capacity of 45 cubic inches.

e. Choosing to attach the cylinder to the gate frame yoke by use of a flange, enter Figure D-23 and find square and rectangular flanges. For use at near full pressure the square front flange is required. Select NFPA Style MF5.

f. The example installation can be easily operated by a hand pump. For the 3000 psi requirement, select a pump with about a 3/4 in. piston. Displacement for each comfortable stroke will be about 0.25 cu in. and about 6.5 strokes will move the gate up one inch. Several pumps meeting these requirements are obtainable with integral reservoirs that are equal to or greater than the minimum capacity requirement of 45 cu in.

g. Assuming that the hydraulic lines are to be buried separately from the air vent, stainless steel is the required material. 1/4 inch diameter would carry the required flow of oil but 3/8 inch will probably justify its extra cost in effort saved. Wall thickness should be 0.028 inches.

h. Select a four-way rotary selector valve ported for 3/8 tubing. For this hand-powered installation a closed center will give the desired circulation pattern.

i. The relief valve for the opening line should be set initially

$$\text{for } p = \frac{\text{thrust + gate weight}}{\text{net area of piston}} = \frac{(4500 = 200)\ \text{lb}}{1.657 \quad \text{in}^2} = 2{,}836 \text{ psi.}$$

The closing line should be limited to

$$p = \frac{\text{thrust - gate weight}}{\text{full area of piston}} = \frac{(4500 - 200)\ \text{lb}}{3.142 \quad \text{in}^2} = 1{,}369 \text{ psi.}$$

j. Compare the cost of a 2" cylinder plus hose and components for 2,850 psi with the cost of a 2½" cylinder plus hose and components for 1,877 psi. (Net area = 2.504 in^2)

VII. OPERATION AND MAINTENANCE

Any system of moving parts must have some degree of maintenance to assure reliability. In either system described here, it is essential that the gate slide and the opening be kept free of trash which might obstruct the movement of the slide. The operator must learn to distinguish between a reasonable force to move the gate and an excess force which can damage the system. Here the pressure gage can prove invaluable to the hydraulic system.

The mechanical system requires lubrication of the threaded stem. Stem guides must be maintained in alignment so that excess friction and/or buckling of the stem do not become a problem. A powered system must be tested for its safety devices (travel and torque limit switches), and the electical or fuel system components must be serviced for their particular requirements.

The hydraulic system contains synthetic seals which require occasional flexing (two to four month intervals) to avoid a permanent set or adherence to the sealing surfaces. (A complete cycle is not necessary). The operator should check relief valves after a long idle period by building pressure to the relief level against closed shutoff cocks (or a closed-center selector valve) before directing the pressure to the cylinder.

VIII. SAMPLE MATERIAL SPECIFICATION

A. Hydraulic Controls

SAMPLE MATERIAL SPECIFICATION

310. HYDRAULIC CONTROLS

1. SCOPE

This specification covers the quality of hydraulic controls for slide gates.

2. GENERAL REQUIREMENTS

The hydraulic controls, including cylinder, pump, valves, lines and fittings, shall conform to the requirements of the Joint Industry Conference (JIC) Hydraulic Standards for Industrial Equipment, or National Fluid Power Association.

3. CYLINDER

The cylinder shall be selected from the JIC Interchangeable Series rated for 2000 psi operating or 3000 psi non-shock loading.

The piston rod shall be stainless steel with threads and wrench flats machined as required to meet mounting requirements as shown on the drawings.

Seals for the piston and the rod bearing shall be the multiple-V type or shall have equivalent sealing characteristics. A metallic external wiping ring shall be incorporated with the rod bearing.

4. PUMP

A hand operated pump shall be capable of developing the design pressure with not more than 60 pounds force on the handle. It shall be equipped with a check valve to prevent backflow between power strokes.

A pump for use with engine or electric motor drive shall deliver oil at the specified rate and pressure without overload on the power unit. The pump and power unit shall be aligned so that bearing loads, stresses in connecting elements and losses due to friction are no greater than for normal power transmission.

5. RESERVOIR

A reservoir shall be supplied with capacity as specified or shown in the drawings. Provision shall be made for filtering the hydraulic fluid during filling. Piping for the return flow shall enter the reservoir below the normal operating level of the fluid. A breather hole shall be provided and shall be protected by an air cleaner.

6. VALVES

All valves shall have a working pressure rating at least equal to the maximum operating pressures of the system.

The control valve shall be a 4-way rotary selector valve of the disc type, equipped for oil service. The seals shall limit internal leakage to 1 drop per minute at the rated pressure. External leakage shall be zero. The center shall be closed or tandem as specified or shown on the drawings.

Relief valves shall be adjustable within the range of 50% to 100% of maximum rated pressure. The adjustment shall be secured by a locknut or protective cover.

7. HYDRAULIC LINES

All hydraulic lines shall have working pressure ratings at least equal to the maximum operating pressure of the system with a safety factor (based on bursting strength) of 4.

Hydraulic lines that will be located under water or inaccessible for regular inspection shall be stainless steel tubing or pressure hose of reinforced synthetic meeting specification SAE 100R7 or 100R8. Fittings for either tubing or hose shall be stainless steel. Hose fittings shall be permanently attached by factory methods. Fittings shall allow no leakage and shall not unduly restrict flow in the passages they connect.

For that part of the piping protected from the weather and accessible for regular inspection, seamless carbon steel tubing can be used. Fittings shall have corrosion protection of cadmium plating or equal. If dissimilar metals must be joined, protection against galvanic corrosion shall be provided.

Metallic hose couplings that will be dragged into place in a conduit shall have a wrapping of coal-tar tape of thickness sufficient to provide a waterproof cover after installation.

8. HYDRAULIC FLUID

Hydraulic fluid shall be supplied in accordance with the manufacturer's recommendations for the equipment supplied and the operating conditions stated under Construction Details.

9. INSTALLATION INSTRUCTIONS

The manufacturer shall submit complete installation data including instructions for adjustment for all components supplied for this system.

10. PAINTING

Each item of equipment shall have paint protection for all metal except stainless steel or electroplated metallic surfaces.

The cylinder and other components that will be submerged shall have protection against such exposure. In the absence of a paint option certified by the manufacturer for such conditions, these items will be painted by System I under Construction Specification 82, Cleaning and Painting Metalwork.

Other components, housed in the control station, shall have paint coatings equal to Paint System D or E under Construction Specification 82.

B. Installing Hydraulically Operated Slide Gates

SAMPLE CONSTRUCTION SPECIFICATION

210. INSTALLING HYDRAULICALLY OPERATED SLIDE GATES

1. SCOPE

The work shall consist of furnishing and installing hydraulically operated slide gates, complete with all controls and other necessary appurtenances.

2. MATERIALS

The gates and controls furnished shall conform to the requirements of Material Specifications 128, 134 and 300. All gates shall be furnished complete with hydraulic hoisting equipment and other necessary appurtenances.

3. INSTALLING GATES

The Contractor shall install the gates in a manner that will prevent leakage around the seats or binding of the gates during operation.

Surfaces of metal against which concrete will be placed shall be unpainted and free from oil, grease, loose mill scale, surface rust and other debris or objectionable coatings.

Anchor bolts, thimbles and spigot frames shall be secured in true position in the forms and held in alignment during the placement of concrete.

Concrete surfaces against which rubber seals will bear or against which flat frames or plates are to be installed shall be finished to provide a smooth and uniform contact surface. When flat frames are installed against concrete, a layer of bedding mortar shall be placed between the frame and the concrete.

4. INSTALLING HYDRAULIC ASSEMBLY

The hydraulic cylinder, pump, valves, connecting lines and fittings shall be installed in accordance with the manufacturer's recommendations and as shown on the drawings, unless otherwise approved by the Engineer.

The cylinder shall be mounted as shown on the drawings. Alignment shall be established so that neither gate nor cylinder will bind during any phase of operation.

5. OPERATIONAL TESTS

After the gate and hydraulic lift assembly have been installed, they shall be cleaned, lubricated and otherwise serviced by the Constractor in accordance with the manufacturer's instructions.

The gate will be required to maintain a set position for twenty-four (24) hours with a maximum permissible movement due to internal leakage of 0.25 inches. The Contractor shall test the gate and hydraulic lift assembly by operating the system several times throughout its full range of operation. He shall make any changes and adjustments that are necessary to insure satisfactory operation of the gate system subject to approval of the Contracting Officer.

6. MEASUREMENT AND PAYMENT

The work will not be measured. Payment for the hydraulically operated slide gate assembly will be made at the contract lump sum price. Such payment will constitute full compensation for all labor, materials, equipment and all other items necessary and incidental to the completion of the work including furnishing and installing anchor bolts, housing and all specified appurtenances and fittings.

7. ITEMS OF WORK AND CONSTRUCTION DETAILS

Class of gate - 00-00 (seating - unseating head)
Type of frame (flat, spigot, flange, etc.)
Type and size of opening (square, round, etc.)
Type of wedge (cast iron, bronze, etc.)
Type of seating surfaces (cast iron, bronze, etc.)
Special gate requirement (self contained, nonrising stem, flush bottom opening, etc.)
Type, capacity of hydraulic control system

The stem block shall be shaped so as to turn in the gate recess for threading to the piston rod.

The maximum operating pressure for this system (opening) will be ______ psi.

The operating pressure for closing will be ____ psi.

The range of temperature for operation of this system will be from -____ °F to +____ °F.

The cylinder shall have _____" bore, _____" stroke _____ mounting style. Piston rod extensions, wrench flat and port locations shall be included as detailed on the drawings.

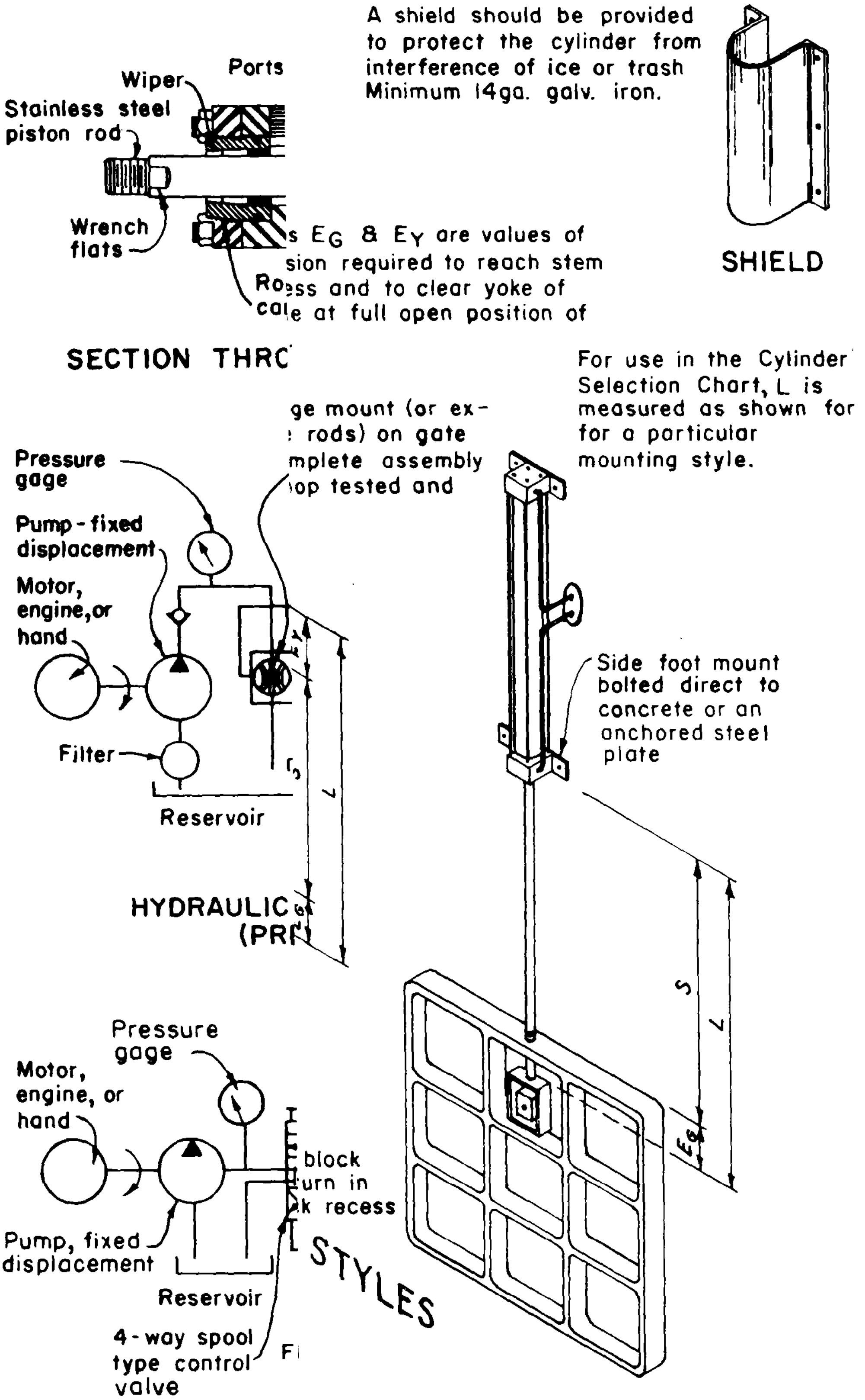
The pump shall have a pressure capability of _____ psi. Volume of flow shall be in the range _______ (gpm, cu in/min) to _______ (gpm, cu in/min).

The reservoir shall have a minimum capacity of ______ cubic inches.

The control valve shall have a (n) (closed or tandem) center and ports. shall be size _______ with straight threads.

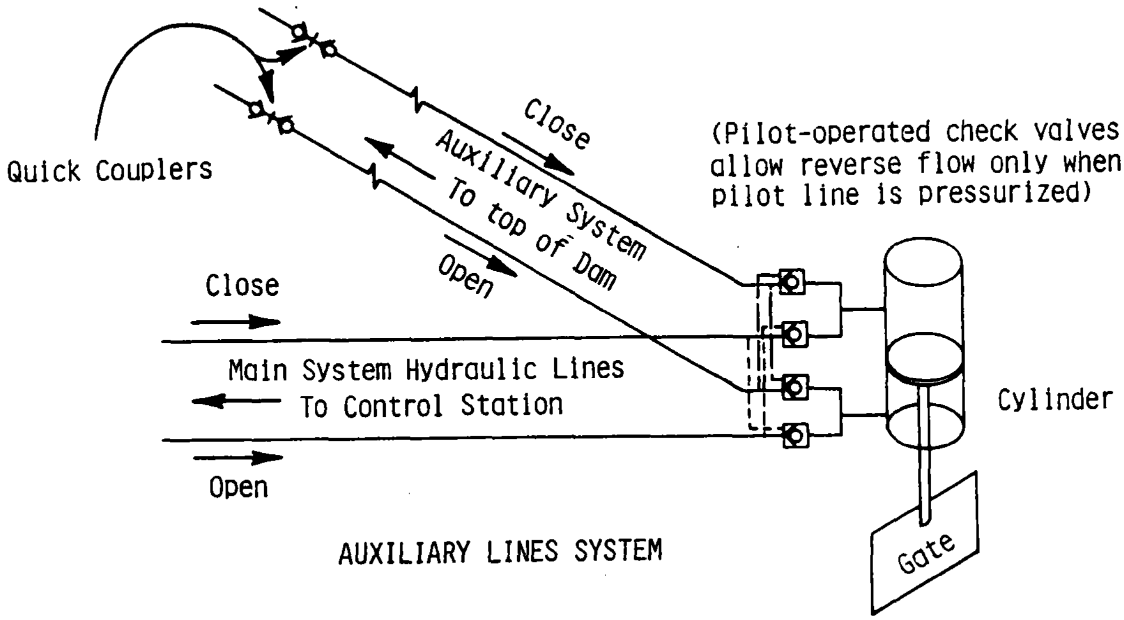
The relief valves shall be adjustable within the range of _______ psi to _______ psi. The initial setting(s) shall be _______ psi (___, ___, ___, respectively) as detailed on the drawings.

Measurement and Payment will be in accordance with Section 6.

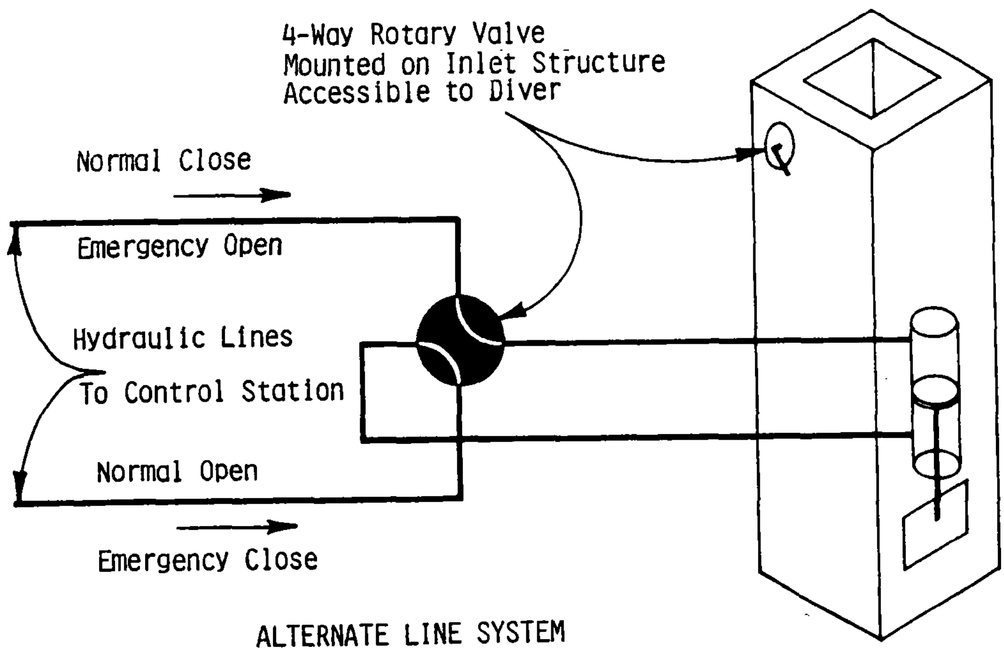


HYDRAULIC F
(ALTE

FIGURE D-22a
TYPICAL DETAILS FOR
AULIC CYLINDER GATE CONTROLS



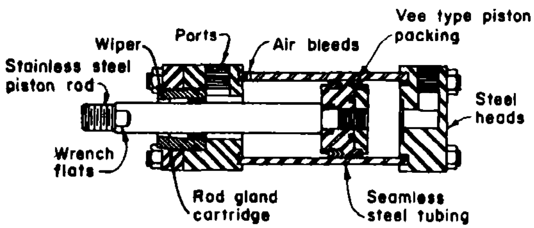
AUXILIARY LINES SYSTEM



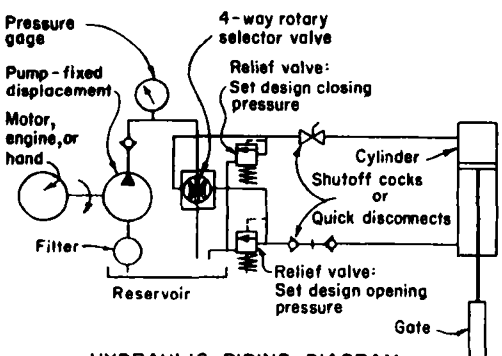
ALTERNATE LINE SYSTEM

FIGURE D-22b

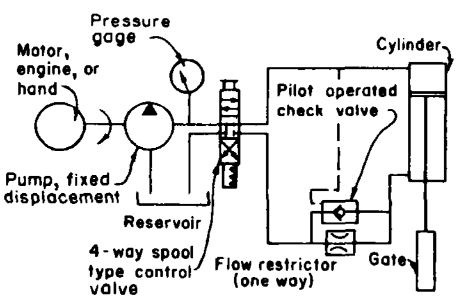
ALTERNATE CONTROL DETAILS
(Reserve for Line Failure)



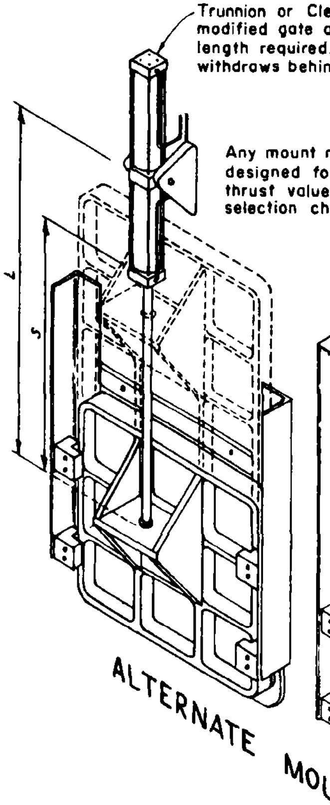
SECTION THROUGH TYPICAL CYLINDER

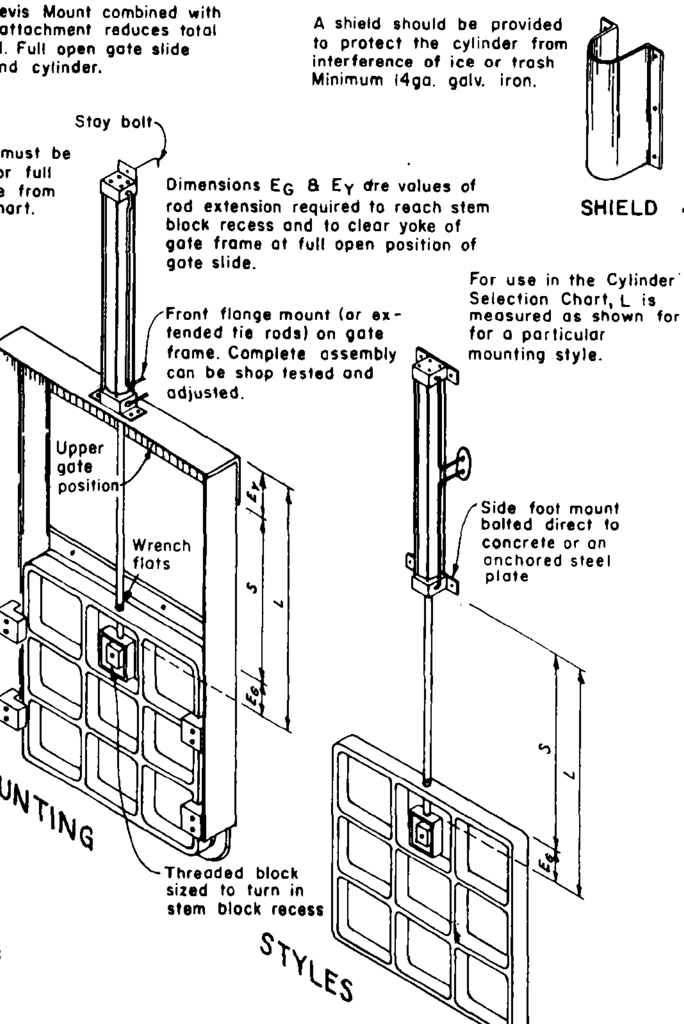


HYDRAULIC PIPING DIAGRAM
(PREFERRED)

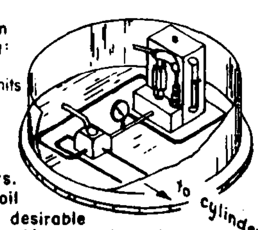


HYDRAULIC PIPING DIAGRAM
(ALTERNATE)





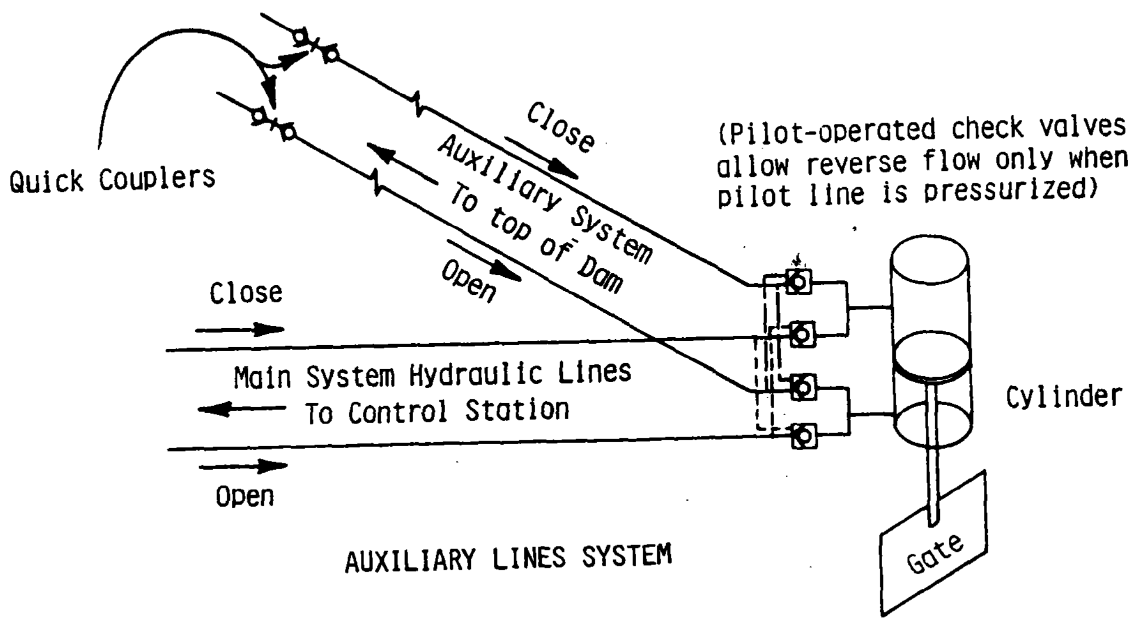
Typical control station includes the following: pump, 4-way valve, reservoir. Assembled units shown at approximate scale in 30" manhole frame. Lid should be secured by lock or pentagonal head bolts. Pressure gauge and oil level sight gauge are desirable optional equipment for this control station.



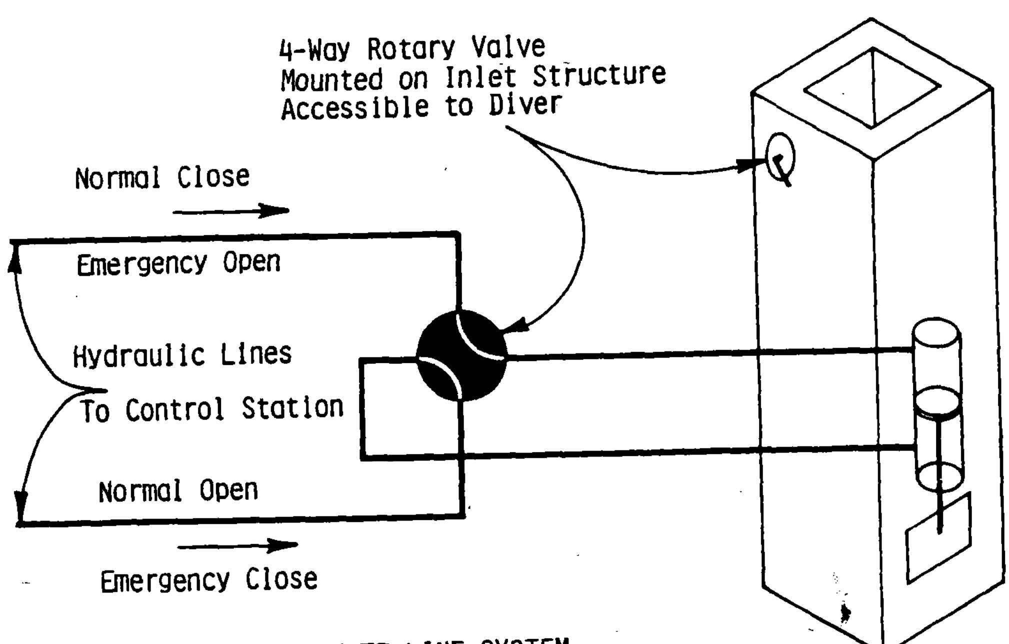
CONTROL STATION

FIGURE D-22a
TYPICAL DETAILS FOR
HYDRAULIC CYLINDER GATE CONTROLS
EWP Unit Portland, Oregon

Revised 6-82



AUXILIARY LINES SYSTEM



ALTERNATE LINE SYSTEM

FIGURE D-22b

ALTERNATE CONTROL DETAILS
(Reserve for Line Failure)

Parker Series 2H
Heavy Duty Hydraulic Cylinders

Specifications
Mountings

STANDARD SPECIFICATIONS

- HEAVY DUTY SERVICE—J.I.C. SPECIFICATIONS AND ANS1 B93. 15-1971 MOUNTING DIMENSION STANDARDS
- STANDARD CONSTRUCTION—SQUARE HEAD—TIE ROD DESIGN
- NOMINAL PRESSURE—3000 P.S.I. *(5000 P.S.I. NON-SHOCK)
- STANDARD FLUID—HYDRAULIC OIL
- STANDARD TEMPERATURE −10°F. TO +165°F.
- BORE SIZES—1½" THROUGH 8" (LARGER SIZES AVAILABLE)
- PISTON ROD DIAMETER—⅝" THROUGH 5½"
- MOUNTING STYLES—18 STANDARD STYLES AT VARIOUS APPLICATION RATINGS
- STROKES—AVAILABLE IN ANY PRACTICAL STROKE LENGTH
- CUSHIONS—OPTIONAL AT EITHER END OR BOTH ENDS OF STROKE. "FLOAT CHECK" AT CAP END.
- ROD ENDS—THREE STANDARD CHOICES—SPECIALS TO ORDER

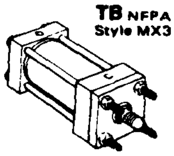
*If hydraulic operating pressure exceeds 3000 PSI, send application data for engineering evaluation and recommendation. See page 156 for actual design factors.

In line with our policy of continuing product improvement, specifications in this catalog are subject to change.

AVAILABLE MOUNTINGS AND WHERE TO FIND THEM

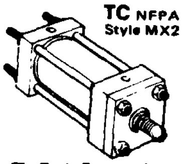
NOTE: Series 2H Hydraulic Cylinders fully meet J.I.C. Standards and ANSI Standard B93.15-1971 for Mounting Dimensions for Square Head Industrial Fluid Power Cylinders.

TB NFPA Style MX3



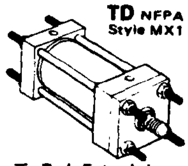
Tie Rods Extended Head End, Style TB.
1½"-8" Bores, Page 54.

TC NFPA Style MX2



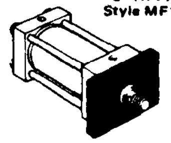
Tie Rods Extended Cap End, Style TC.
1½"-8" Bores, Page 54.

TD NFPA Style MX1



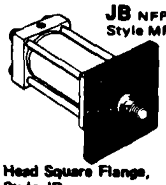
Tie Rods Extended Both Ends, Style TD.
1½"-8" Bores, Page 54.

J NFPA Style MF1



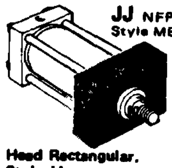
Head Rectangular Flange, Style J.
1½"-8" Bores, Page 56;

JB NFPA Style MF5



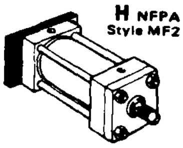
Head Square Flange, Style JB.
1½"-8" Bores, Page 58;

JJ NFPA Style ME5



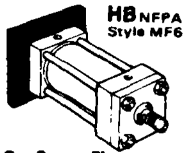
Head Rectangular, Style JJ.
1½"-8" Bores, Page 56;

H NFPA Style MF2



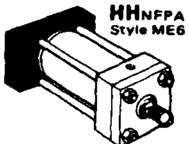
Cap Rectangular Flange, Style H.
1½"-8" Bores, Page 58;

HB NFPA Style MF6



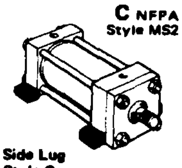
Cap Square Flange, Style HB.
1½"-8" Bores, Page 58;

HH NFPA Style ME6



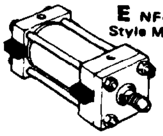
Cap Rectangular Style HH.
1½"-8" Bores, Page 58;

C NFPA Style MS2



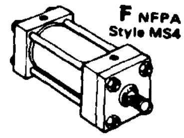
Side Lug Style C.
1½"-8" Bores, Page 60;

E NFPA Style MS3



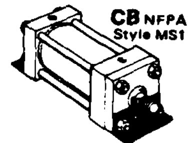
Centerline Lugs, Style E.
1½"-8" Bores, Page 60;

F NFPA Style MS4



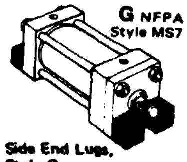
Side Tapped Style F.
1½"-8" Bores, Page 60.

CB NFPA Style MS1



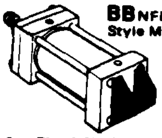
Side End Angles, Style CB.
1½"-8" Bores, Page 62.

G NFPA Style MS7



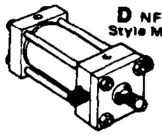
Side End Lugs, Style G.
1½"-8" Bores, Page 62.

BB NFPA Style MP1



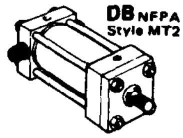
Cap Fixed Clevis, Style BB.
1½"-8" Bores, Page 62;

D NFPA Style MT1



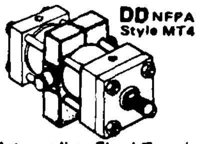
Head Trunnion, Style D.
1½"-8" Bores, Page 64;

DB NFPA Style MT2

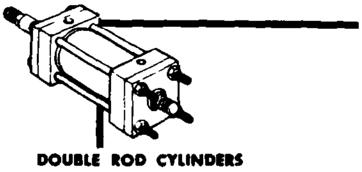


Cap Trunnion, Style DB.
1½"-8" Bores, Page 64;

DD NFPA Style MT4



Intermediate Fixed Trunnion Mounting, Style DD.
1½"-8" Bores, Page 64;



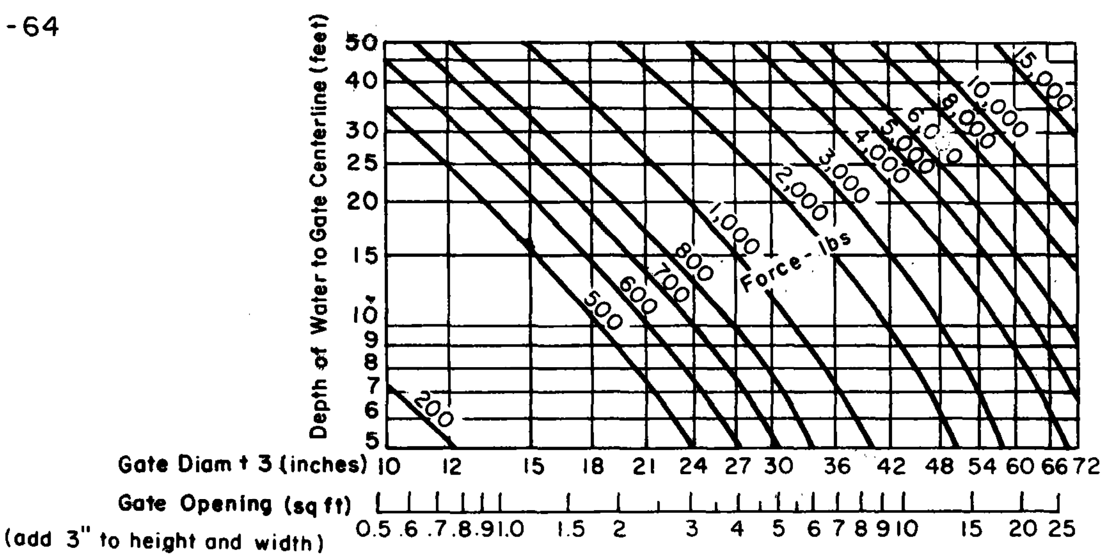
DOUBLE ROD CYLINDERS
Most of the above illustrated mounting styles are available in double rod cylinders. See Catalog Page 66.

Parker Cylinder Division
501 So. Wolf Road
Des Plaines, IL 60016
Chicago (Des Plaines), IL
312/298-2400

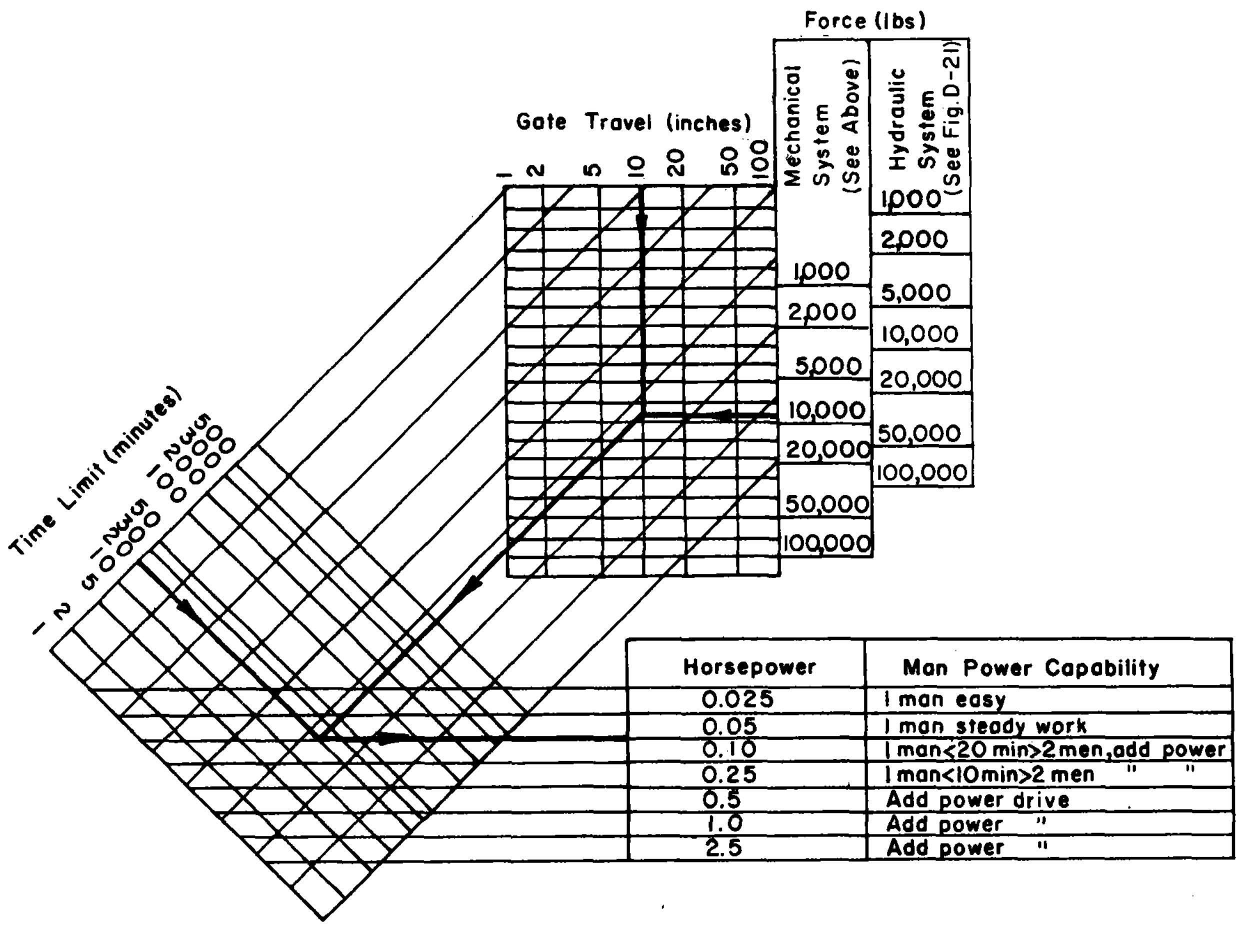
Courtesy of Parker Fluidpower

Note:
Cylinders of several manufacturers are available with identical mounting dimensions (for same bore and stroke) based on NFPA mounting style.
Check manufacturer's recommendation of maximum pressure for specific mounting style.

FIGURE D-23
HYDRAULIC CYLINDER INTERCHANGE CHART
WNTC Portland, Oregon
12-82



FORCE IN MECHANICAL LIFT



EVALUATION OF POWER REQUIREMENT

FIGURE D-24
CONTROL OPERATION
MANUAL vs POWER
EWP Unit Portland, Oregon

Pressure Rating		1000 psi	2000 psi	3000 psi
Material	Diameter	Wall Thickness		
Steel Tubing	1/4	0.020	0.020	0.028
(1010&1015)	3/8	0.020	0.028	0.042
½Hard Copper	1/2	0.020	0.042	0.056
Bundyweld	3/4	0.028	0.058	0.083
Stainless Steel	1/4	0.020	0.020	0.022
Annealed	3/8	0.020	0.022	0.032
	1/2	0.020	0.025	0.042
	3/4	0.025	0.042	0.065

		Working Pressure	
Steel Pipe	Specification	Sch 40	Sch 80
	1/4	2100	4350
	1/2	2300	4100
	3/4	2000	3500
Hose	Specification SAE	100R7	100R8
Synthetic	1/4	3000	5000
Reinforced	3/8	2250	4000
	1/2	2000	3500
	3/4	1250	2250

		Friction Losses (psi per foot) Velocity 5 fps	10 fps	15 fps
Pipe Sch 40	1/4	0.67	1.64	1.92
	1/2	0.24	0.49	0.68
	3/4	0.14	0.27	0.78
Hose	1/4	1.57	3.00	4.49
	3/8	0.69	1.34	2.02
	1/2	0.39	0.76	1.13
	3/4	0.17	0.34	0.50
Tubing	1/4	Estimate friction in tubing		
	3/8	slightly higher than for hose		
	1/2	based on the inside diameter.		

Figure D-25

SECTION E - CONDUIT

I. INTRODUCTION

One of the more critical elements in the safety of a dam is the conduit that carries water through the embankment. Not only must the conduit be watertight against internal water pressures, it must be designed to carry exterior vertical and transverse loads to resist structural failure. It must be set on a grade that takes into account the magnitude of foundation settlement and the variation of this settlement along its length. It must allow for readjustment of the individual pipe lengths without failure of the joints. These joints must allow for "stretch" in the conduit as a result of foundation displacement. And lastly, the backfill must be carefully placed along the conduit so that seepage water will not find a more favorable path along the contact surface than that it must face through the embankment itself.

These conditions are met in part by the selection of the proper conduit type and strength, whether it be a rigid pipe in a concrete cradle, a flexible pipe, or a monolithic box, set on a grade considering camber requirements. Adding anti-seep collars insures the path along the contact zone will be a longer seepage line than that through the embankment. Of course all of these precautions mean little if the installation does not conform to the requirements of the construction specifications.

II. GENERAL CRITERIA

Because the conduit is such a vital part in the safety of the dam, criteria is very explicit and limiting in those cases where loss of life could result from embankment failure. To ensure that these limiting criteria are not overlooked, the following tabulation of existing engineering memoranda is included and these must be complied with as each restriction applies:

1. National Engineering Manual, Part 520.20 and TR 60, Earth Dams

2. National Engineering Manual, Part 543, Corrugated Aluminum Pipe

In addition to the manual, procedures for analysis are continued in the following:

1. NEH, Section 6, Structural Design

2. Technical Release No. 5, The Structural Design of Underground Conduits

3. Technical Release No. 18, Joint Gap Computations for R/C Pipe Drop Inlet Barrels

Appropriate specifications include:

Construction Specifications
- No. 41, R/C Pressure Pipe Spillway Conduits
- No. 51, Corrugated Metal Pipe Conduits and Drains
- No. 52, Steel Pipe Conduits

Materials Specifications
- No. 541, R/C Pressure Pipe
- No. 542, Concrete Culvert Pipe
- No. 551, Zinc-Coated Iron or Steel Corrugated Pipe
- No. 552, Aluminum Corrugated Pipe
- No. 553, Steel Pipe and Fittings

III. CONDUIT TYPES

A. Precast Concrete Pipe

Four types of precast pipe are recommended as suitable for use as a conduit through an embankment.

1. ASTM C361, R/C Low Head Pressure Pipe
2. AWWA C300, R/C Pressure Pipe Steel Cylinder Type
3. AWWA C301, Prestressed Concrete Pressure Pipe Steel Cylinder Type
4. AWWA C302, R/C Pressure Pipe Non-Cylinder Type

The procedures presented in Technical Release No. 5 should be used in determining structural requirements of the pipe.

General details of precast pipe are shown on Figure E-1. The listing on this figure of diameters and different types of pipe is all inclusive. Incremental sizes and some types are not available from all plants. Freight costs can add considerably to construction costs for a particular job and should be a consideration in comparing alternate details.

In addition to the precast pipe listed above, a concrete cylinder pipe complying with Federal Specification SS-P-381 has been used in composite construction as a liner in a job-placed reinforced concrete conduit.

Conduit wall thicknesses have been listed in Table E-1 for ready reference as required.

B. Flexible Conduits

Of the flexible conduits, a corrugated metal is the most commonly used. Corrugations may be annular or helical and the conduit made of galvanized iron or aluminum.

Use of corrugated pipe is limited to fill heights of 25'-0" or less.

Aluminum pipe shall not exceed 36" diameter and internal pressures shall be limited to 15 feet of head. Aluminum material shall not be used where the pH is less than 4 or greater than 9.

Where the product of the storage in acre feet times the height of the dam[1] is less than 3000 and meets the conditions above, the following tables apply:

Recommended corrugated metal pipe gages for various pipe diameters and fill heights are given in

1. Table E-3 for corrugated steel.

2. Table E-4 for corrugated aluminum.

Special precautions should be taken in the backfill operation. Because of its light weight, the pipe will be displaced upward when backfilling in the lower third. To avoid this displacement there is a tendency by the construction crew to under-compact this material. This results in a poor contact zone between the soil and conduit with a potential for piping and eventual embankment failure. To insure adequate compaction, the conduit should be preloaded with sandbags to resist the uplift until the lower 120° of the conduit is backfilled. As an alternate the pipe can be bedded in concrete.

Welded steel pipe may be used as a liner for a monolithic conduit of small diameter. As such it no longer is classed as a flexible pipe.

C. Monolithic Conduits

Poured in place conduits are used in many installations for both the small diameter as well as the larger box conduit. In the small diameter conduit a welded steel pipe is used as a liner which serves as an interior form. The joints of this pipe are "stab" type with a rubber ring. A trench is excavated to neat lines and serves as the bottom and side exterior forms for the conduit walls.

On a non-compressible foundation no joints are provided in the concrete. For a compressible foundation a joint similar to the detail shown on Figure E-3 or E-5 is used.

1/ Defined as the difference in elevation in feet between the emergency spillway crest and the lowest point in the original profile on the centerline of the dam.

The concrete and reinforcement requirements of a common form of monolithic conduit are shown on Figure E-2. An analysis by TR-5 procedures for fill heights of 10, 30, and 100 feet over pipe diameters of 30 and 48 inches suggests the relationship of soil types and ditch and projection conditions as shown. The results were used from the assumed settlement ratio of 1.0 after values of 0.5 and 0.75 did not change the calculations significantly.

The V line is located so as to find a section with a maximum shear stress of 70 psi in the compressive zone of the concrete when the vertical load is applied. On the assumption that haunches, in effect, reduce the length of the beam developing moment, the moments induced by the vertical load are easily resisted by a steel area equal to ρ_{bm} (TR-67) for the negative moment zone. This same value as shown on the chart will not exceed ρ_{shy} for the minimum concrete section at the midpoint.

IV. JOINTS

The integrity of the entire installation depends to a great extent on joint detail. For concrete conduits, any rotation due to settlement and elongation of the conduit must take place at the joints. Procedure for calculating joint extensibility is given in Technical Release No. 18.

Recommended joint detail for rigid circular conduits consists of an "O" ring rubber gasket seated in a groove in a steel spigot ring to be inserted in a steel bell. A sectional detail of this joint assembly is shown on Figure E-1. The rest of the joint details shown on this figure are not acceptable in conduits through embankments.

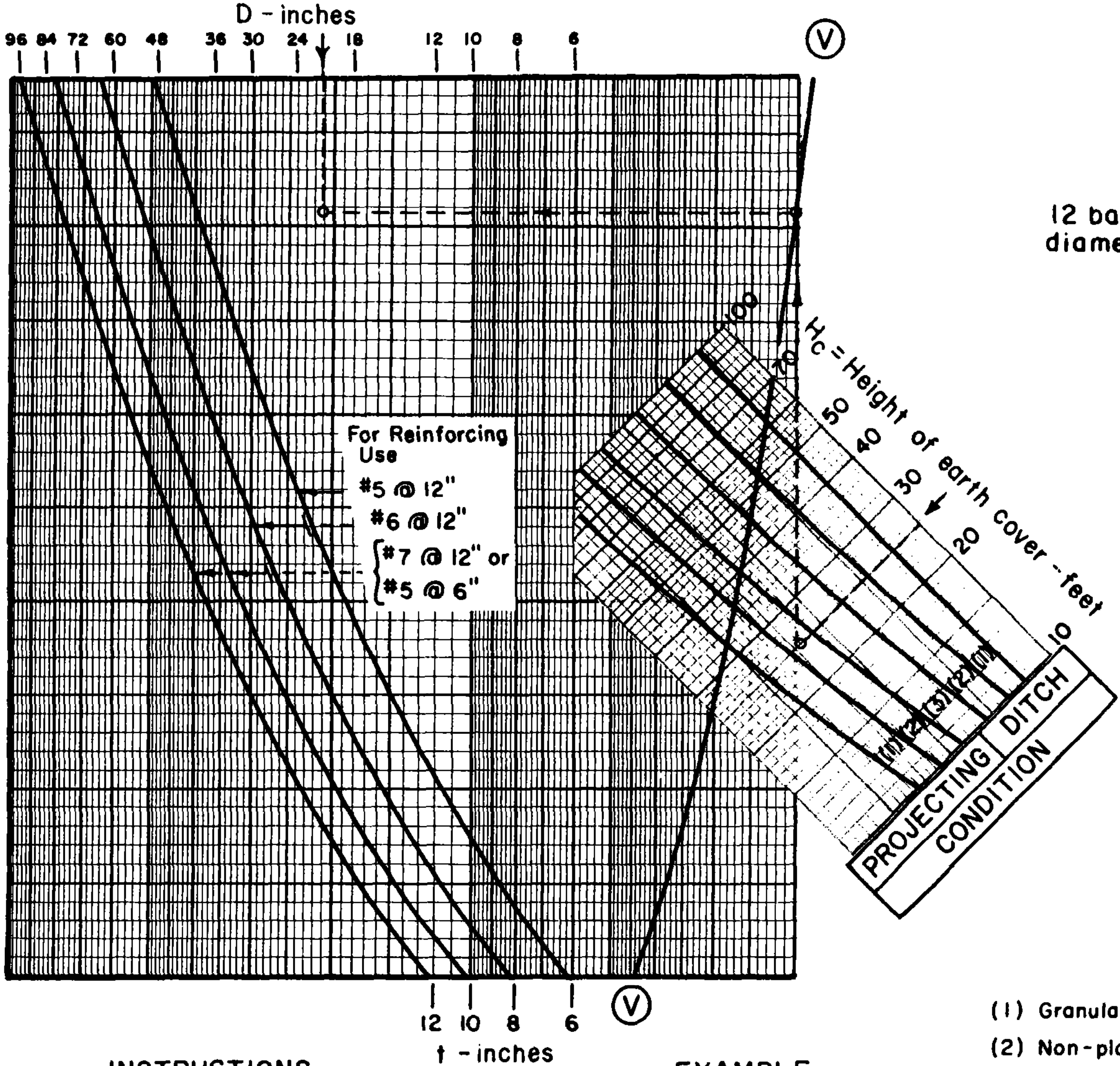
Spigot ring cross section will vary with manfacturer, conduit diameter, and joint extension requirement. In western areas Carnegie shape M 3818 and M 3516 are commonly used. The annular space between the adjacent pipe ends should be filled with a mastic joint sealer for joint flexibility instead of the cement grout normally recommended by the manufacturer.

The bell and spigot joint is used for both the precast pipe as well as the composite construction (shown in Figure E-6).

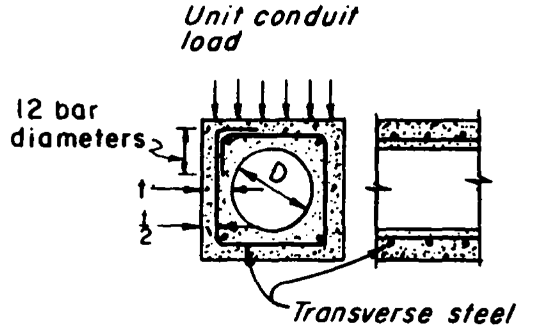
For monolithic concrete conduits with a rectangular opening, the joint detail will vary with conduit size. Several details are shown on Figures E-3 and E-5.

The Carnegie shape joint mentioned above is recommended for welded steel pipe. An alternate joint would be a Dresser coupling. Least desirable is a welded joint.

For corrugated metal conduits, the watertight coupling band is used.



Note:
Provide longitudinal bars to meet T & S requirements



MONOLITHIC R/C CONDUIT

ASSUMPTIONS

1. δ (settlement ratio) = 1.0
2. f'_c = 4,000 psi
3. f_y = 40,000 psi
4. v = 70 psi

SOIL TYPES

(1) Granular	ϕ = 35°,	γ_m = 130 - 140 pcf
(2) Non-plastic	ϕ = 20°, PI < 10,	γ_m = 130 pcf
(3) Plastic	ϕ = 10°, PI > 10,	γ_m = 130 pcf

INSTRUCTIONS

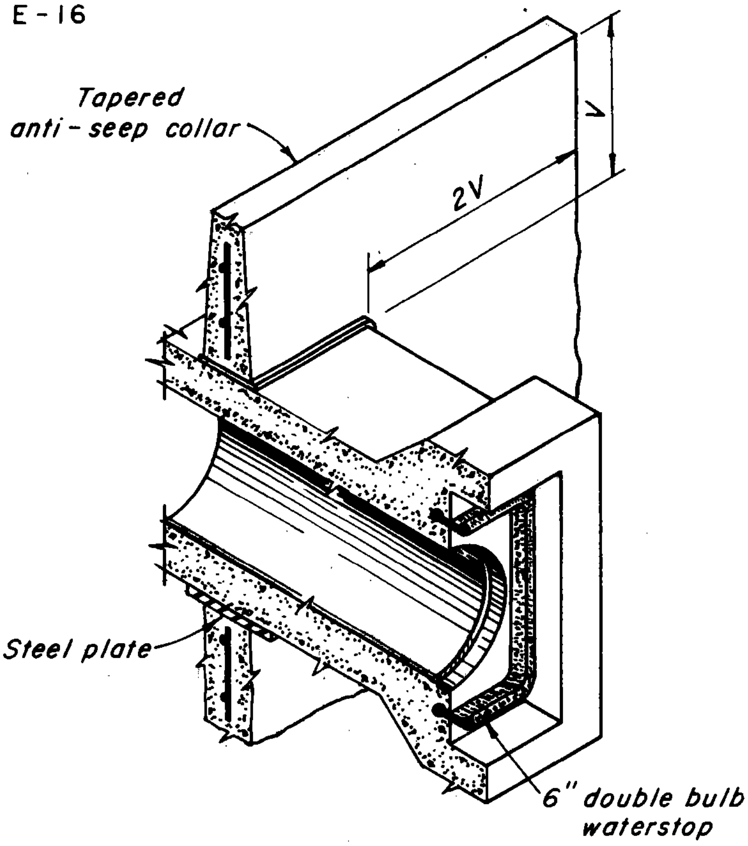
1. Enter with H_c, Soil Type, and Projection Classification (refer TR-5).
2. From intersection move vertically to V line, then horizontally to pipe diameter.
3. Read thickness of conduit at midpoints of top and sides and bar size for hoops or U-bars.
   Thickness of bottom concrete = t + 1"

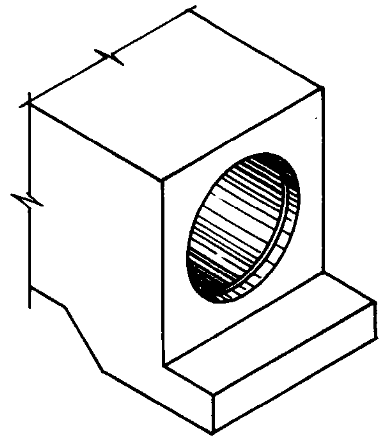
EXAMPLE

Given: Projecting condition
H_c = 25 ft.
D = 21 in.
Soil Type 2

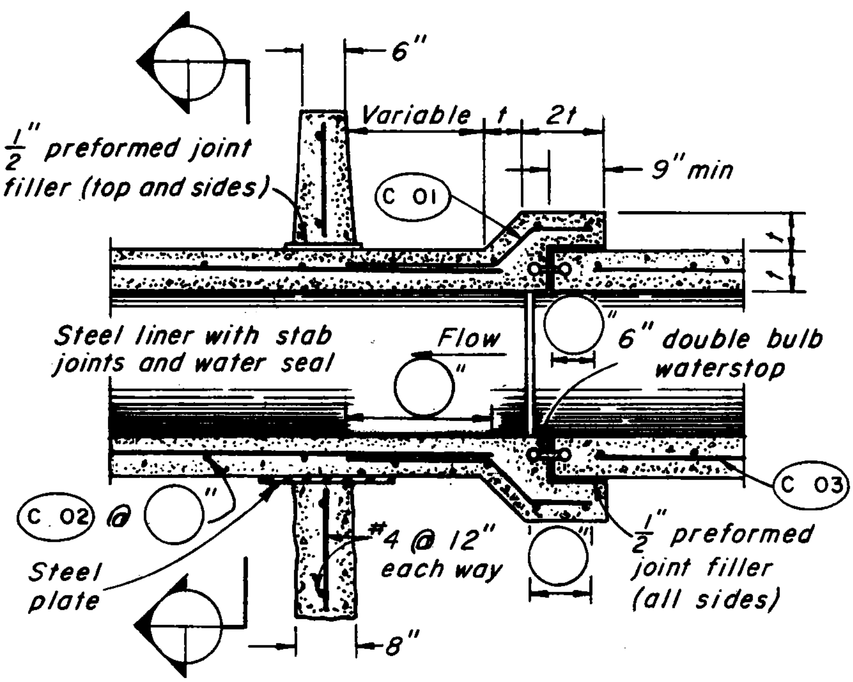
Read: t = 6"
Rebars = #5 @ 12"

FIGURE E-2
MONOLITHIC R/C CONDUIT
WITH STEEL LINER
EWP Unit Portland, Oregon
Revised 6-82

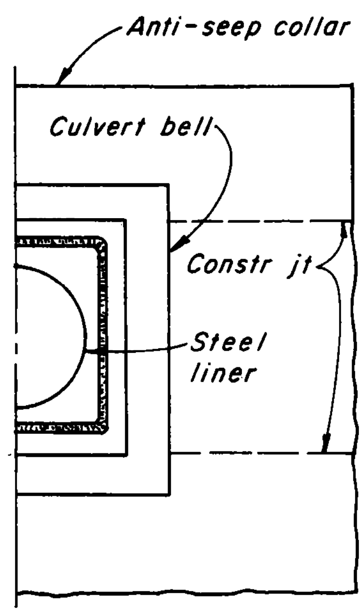




ALTERNATE



SECTIONAL ELEVATION



END VIEW

ANTI-SEEP COLLAR

Note:

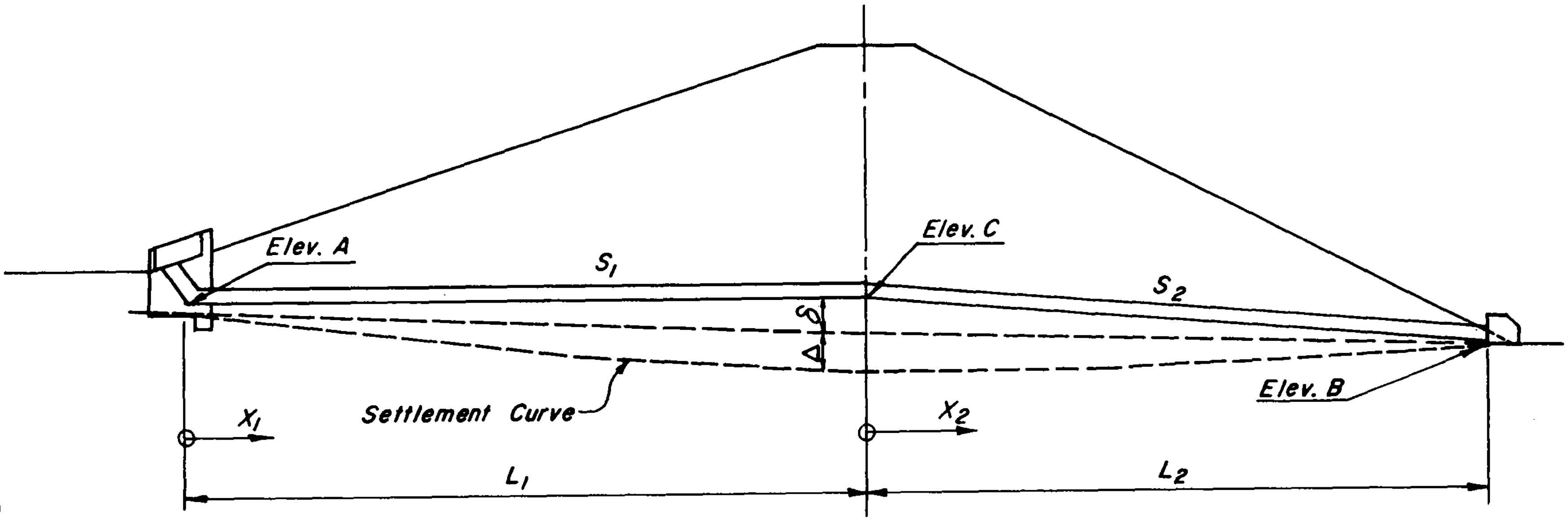
Max. joint spacing = 32.0'

Refer to Figure E-2 for thickness t and reinforcing requirements

FIGURE E-3

R/C MONOLITHIC CONDUIT DETAIL

EWP Unit Portland, Oregon

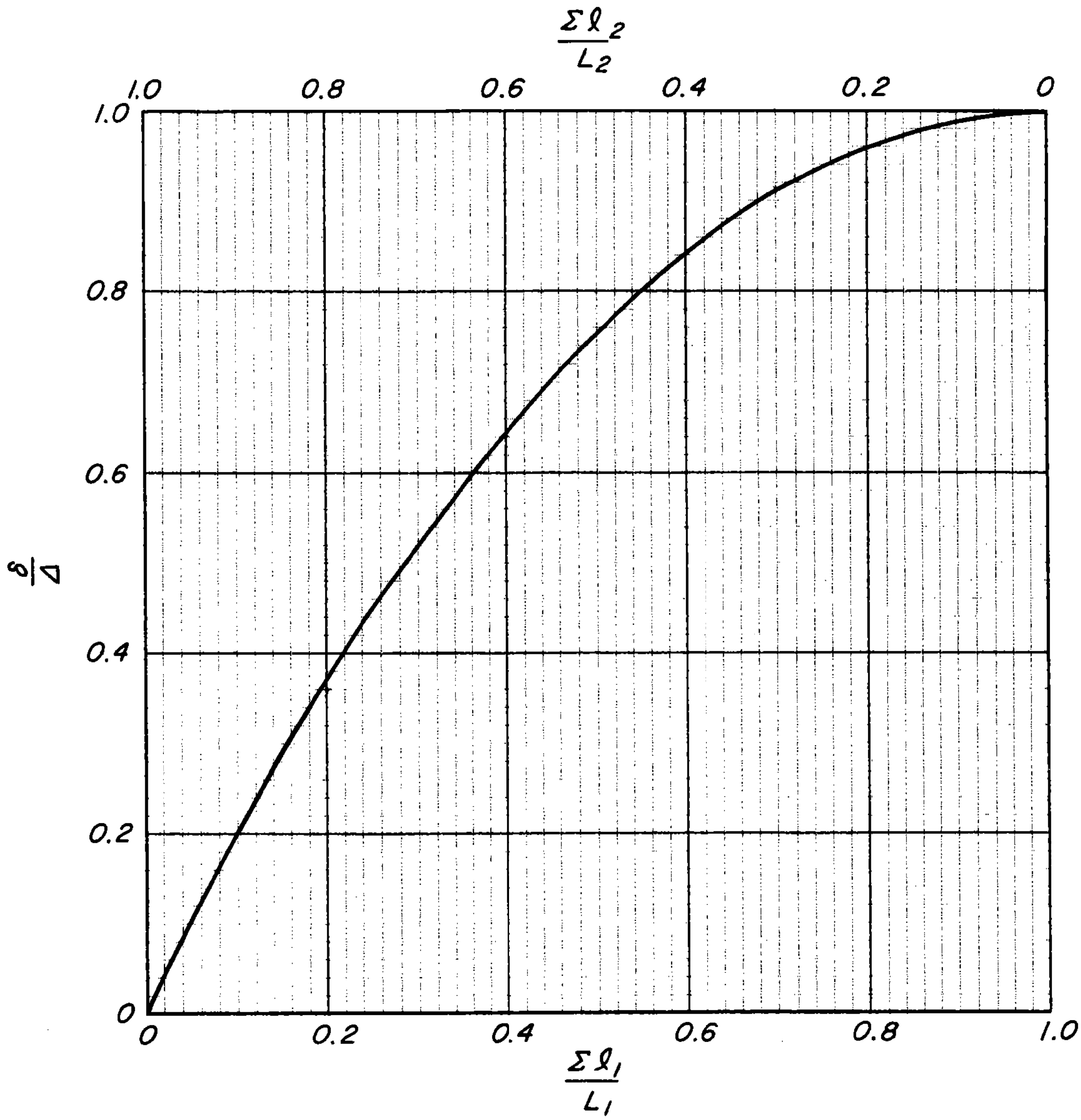


Δ = Max. settlement = δ_{max}

$$S_1 = \frac{\text{Elev. A} - \text{Elev. C}}{L_1}$$

$$S_2 = \frac{\text{Elev. C} - \text{Elev. B}}{L_2}$$

FIGURE E-10
SETTLEMENT CURVE AND SIMPLE CAMBER
EWP Unit Portland, Oregon



$$\delta = \frac{\Delta x_1}{L_1}\left(2 - \frac{x_1}{L_1}\right)$$

$$\delta = \Delta - \frac{\Delta}{L_2^2} x_2^2$$

FIGURE E-11
CONDUIT CAMBER
ON PARABOLIC CURVE
EWP Unit Portland, Oregon

RECOMMENDED GAGES - CORRUGATED METAL PIPE

TABLE E-3

Steel	Standard Corrugations (2-2/3" x 1/2")					
Fill Height	Pipe Diameters					
	To 21"	24	30	36	42	48
	Minimum Gage					
1-15	16	16	16	14	12	10
15-20	16	16	16	14	12	10
20-25	16	16	14	12	10	10
	Wide Corrugations (3' x 1")					
0-20	-	-	-	-	16	16
20-25	-	-	-	-	16	14

TABLE E-4

Aluminum (1)	Standard Corrugations					
	Minimum Thickness (in.)					
1-15	0.06	0.06	0.075	0.075	---	---
15-20	0.06	0.075	0.105	0.105		
20-25	0.06	0.105	0.135	(2)		

(1) Riveted or helical fabrication.
(2) Not permitted.

SECTION F - OUTLET STRUCTURES

Contents

Figures

PLATE F-1

IV. IMPACT BASIN

The impact basin is recommended for use with long duration flows and where the downstream water level will not meet the minimum tailwater requirements for the formation of a hydraulic jump. Entrance velocities should be restricted to less than 30 fps. Figure F-2 is a schematic diagram and a selection chart for various head-conduit size relations within the limits of the hydraulic capacity of this type of structure.

A short length of conduit leading directly into the impact basin should be level or set on a slight positive slope. During low flows, experience has shown that the jet leaving a steeper conduit will miss the impact wall completely.

Impact basins should not be used with open top inlets where heavy or long debris can be expected unless an extensive trash rack is used. Where tumbleweed or similar windblown trash is a problem, it is advisable to screen the basin from above.

This design is fully described in TR 49.

Riprapping the bottom and sides of the downstream channel for a distance equal to one basin width is recommended. For riprap sizes refer to TR 49.

For computing the hydraulics of a full flow conduit system using an impact basin, THE OUTLET WATER SURFACE SHOULD BE ASSUMED TO BE AT THE TOP OF THE BAFFLE SLAB.

A sample of this structure has been included in the completed example in Section H as Figure H-5.

V. SAF BASIN

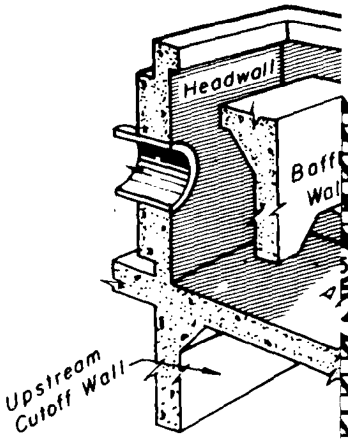
The St. Anthony Falls hydraulic laboratory developed an energy dissipating structure used extensively in the Service. This structure is known as the SAF basin. It is recommended for long duration flows, high entrance velocities and discharges in excess of 400 cfs. This structure has not been standardized because of the number of variables involved so that each installation is a separate design. NEH 14, "Chute Spillways", provides procedures for the hydraulic proportioning of the SAF basin.

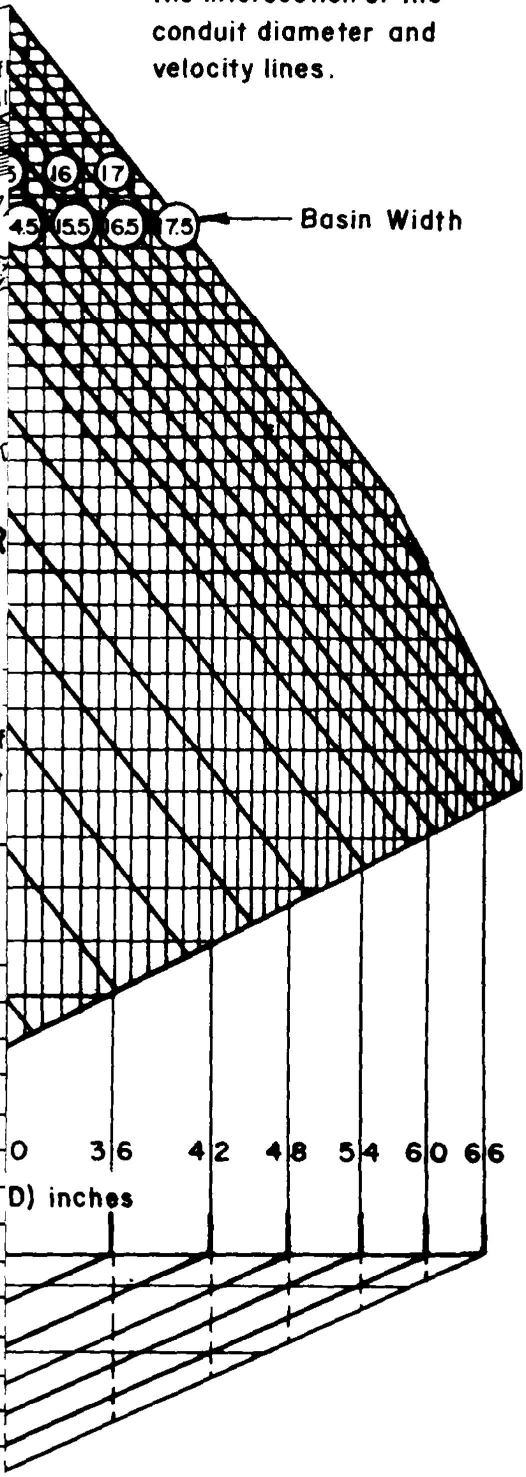
The SAF basin depends on the hydraulic jump for energy dissipation. Unless tailwater satisfies the jump requirements over the major portion of the discharge range ineffective operation results. The ratio, TW/D_2, tailwater depth (TW) to depth required for the jump, (D_2), should be within the limits of 0.8 to 1.2 for the full range of discharge (see Plate F-2). However, for low discharge short duration flows the tailwater rating curve may exceed the TW/D_2 ratio of 1.2 without serious consequence.

Plate F-3 is an excellent illustration of malfunction in a SAF basin because of inadequate tailwater. Loss of a hydraulic control downstream or degradation of the channel is the usual cause of low tailwater. Because of low tailwater, the high velocity jet leaves the structure with little energy loss further aggravating the downstream scour problem.

Elevation of the SAF apron should be established by using the lowest roughness coefficient and a scoured grade line in the hydraulics of the downstream channel. Elevation of the top of the SAF sidewall should be checked using the highest roughness coefficient in the downstream hydraulics.

Note : The basin width selected shall be that width directly above or to the right of the intersection of the conduit diameter and velocity lines.





PER

Example:

Conduit dia –

Velocity – –

At intersection f

Use standard st

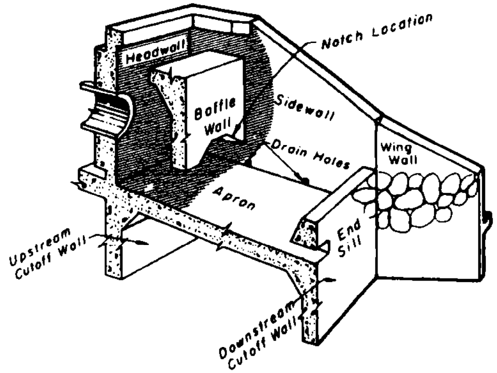
Structure Width feet	Conduit Dia Inches
5	10-18
6	12-21
7	15-24
8	18-30
9	21-33
10	24-36
11	27-42
12	30-48
13	33-51
13.5	33-54
14	36-57
14.5	36-57
15	39-60
15.5	39-60
16	42-63
16.5	42-63
17	45-66
17.5	45-66

* The quar
vary witl

FIGURE F-2

IMPACT BASIN OUTLET STRUCTURE

EWP Unit Portland, Oregon



PERSPECTIVE VIEW

Example:

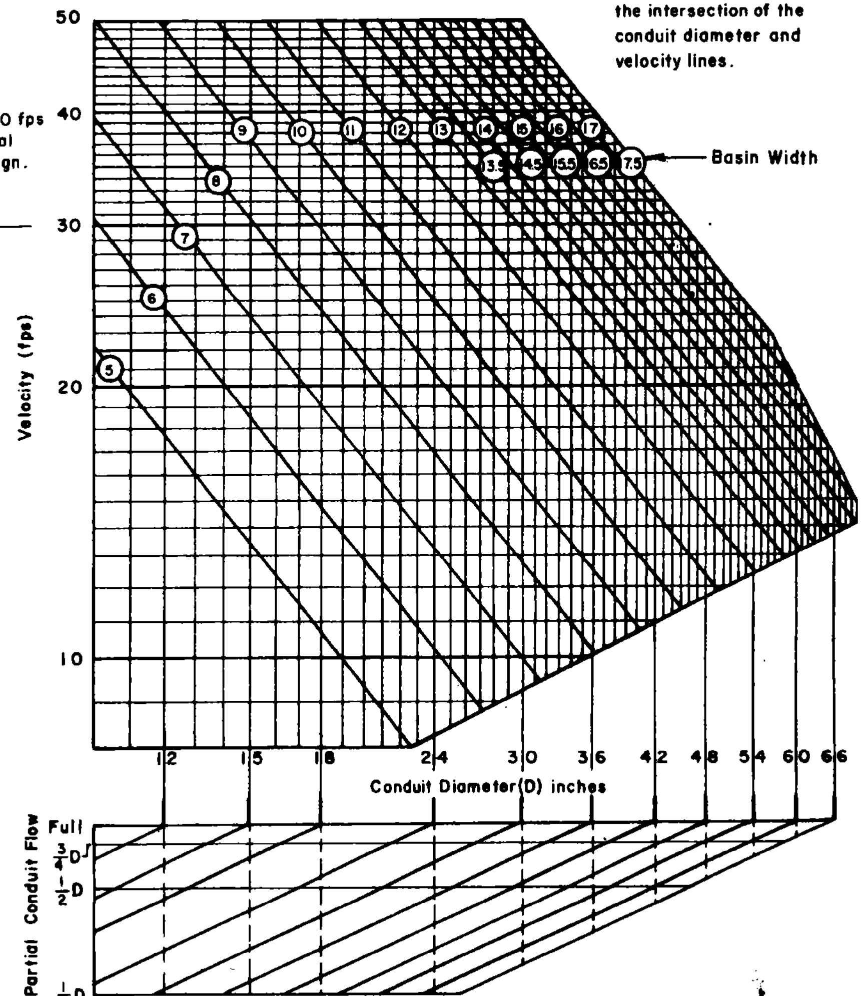
Conduit dia – – – – – – 30 inches (full pipe flow)
Velocity – – – – – – – 20 fps
At intersection find- – – – 10.4 ft basin width
Use standard structure size 11.0 feet

Structure Width feet	Conduit Dia Inches	Quantities *		Std. Drwg. No.
		Concrete-cu.yds	Reinf. Steel-lbs.	
5	10-18	10.0	1500	ES4050
6	12-21	12.5	1900	4060
7	15-24	15.0	2200	4070
8	18-30	20.0	2800	4080
9	21-33	23.0	3300	4090
10	24-36	28.0	3900	4100
11	27-42	33.0	4800	4110
12	30-48	38.0	5700	4120
13	33-51	43.5	6700	4130
13.5	33-54	46.5	7300	4135
14	36-57	50.5	7900	4140
14.5	36-57	55.0	8800	4145
15	39-60	58.5	10,000	4150
15.5	39-60	62.0	10,600	4155
16	42-63	65.0	11,000	4160
16.5	42-63	70.0	12,400	4165
17	45-66	73.5	13,300	4170
17.5	45-66	77.0	14,100	4175

* The quantities listed are approximate and vary with the size of the inlet conduit.

Note : The basin width selected shall be that width directly above or to the right of the intersection of the conduit diameter and velocity lines.

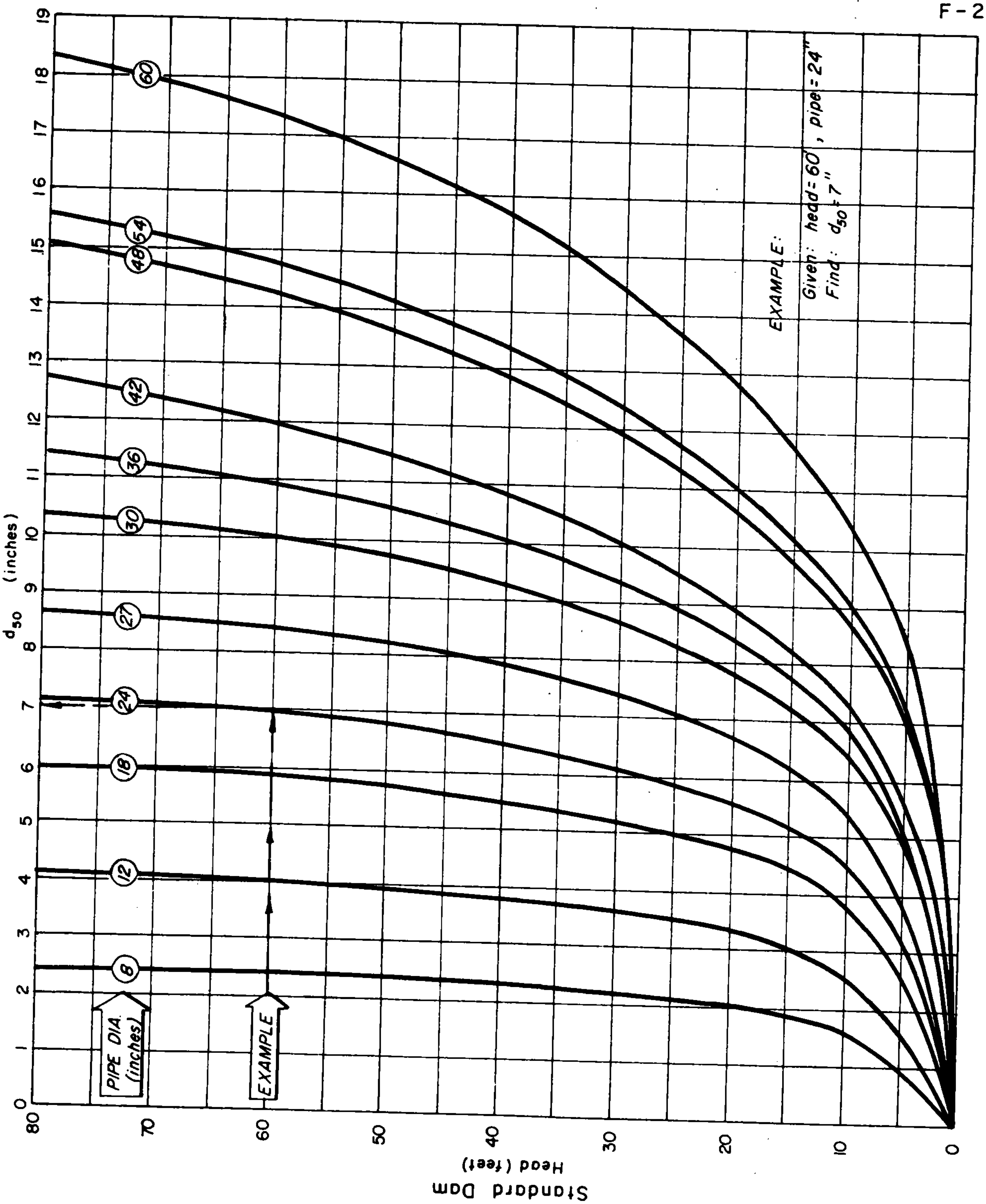
Velocity over 30 fps requires special structural design.



SIZE SELECTION CHART

FIGURE F-2
IMPACT BASIN OUTLET STRUCTURE
EWP Unit Portland, Oregon

Revised 6-82 Reference: USDI Report # HYD-572



Equation analysis for d_{50}

$$d_{50} = \left[\frac{A_p^2 H}{b^2\left[2+(5.2H+28)k_p\right]}\right]^{\frac{1}{3}} \quad (5.96)$$

A_p = Area of the pipe (ft.^{2}) b = bottom width (ft.)

H = Head (ft.) k_p = Head loss coefficient for pipe

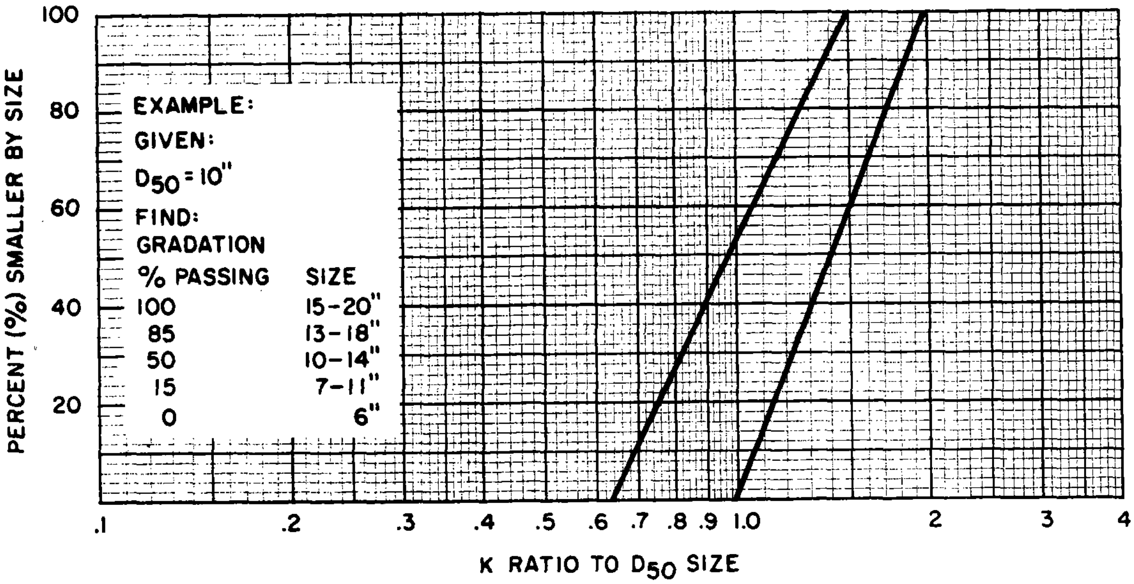
Riprap layer thickness = $3d_{50}$

Filter layer thickness = d_{50}

FIGURE F-3a

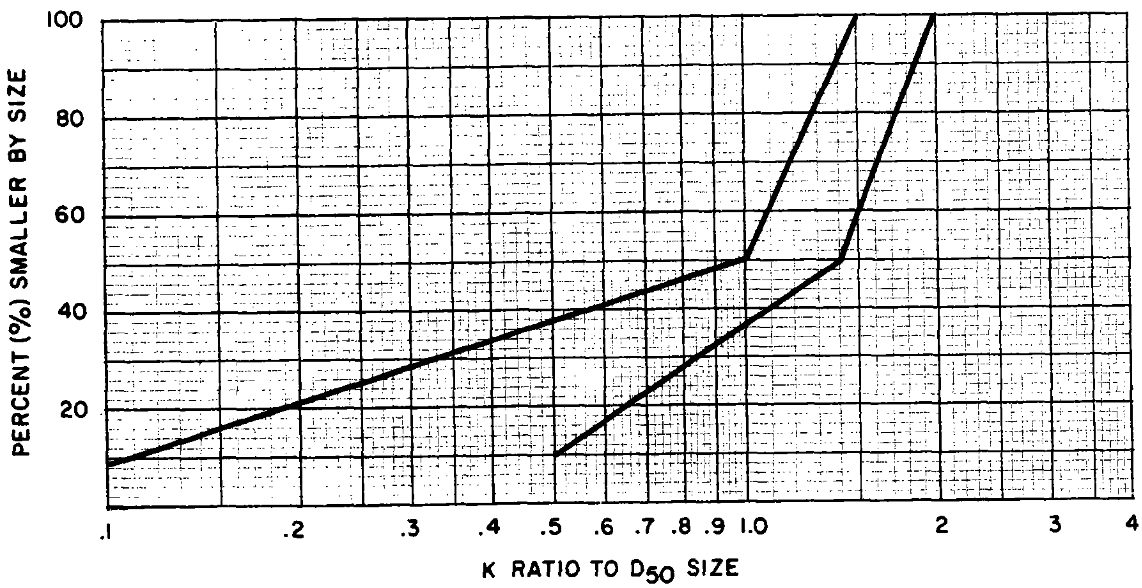
RIPRAP SIZE SELECTION CURVES (d_{50})

EWP Unit Portland, Oregon



UNIFORM ROCK RIPRAP

Use of this uniform gradation might require a 2 or 3 stage filter.



GRADED ROCK RIPRAP

Use of graded riprap might require a 2 stage filter.
The smaller fraction might be subject to removal by high velocity or turbulence.

Figure F-3b

STANDARD PLANS: STANDARD IMPACT BASINS SCHEDULE SHOWING DRAWING NUMBERS, VOLUMES OF CONCRETE, AND WEIGHTS OF STEEL.

STANDARD DETAIL DRAWINGS ES-4WWW	QUANTITIES*	
	STEEL - lbs.	CONCRETE - cu. yds.
ES-4050	1500	10
-4060	1900	12.5
-4070	2200	15
-4080	2800	20
-4090	3300	23
-4100	3900	28
-4110	4800	33
-4120	5700	38
-4130	6700	43.5
-4135	7300	46.5
-4140	7900	50.5
-4145	8800	55
-4150	10,000	58.5
-4155	10,600	62
-4160	11,000	65
-4165	12,400	70
-4170	13,300	73.5
-4175	14,100	77

Key to Drawing Numbers

The drawing numbers of the Standard Detail Drawings for Standard Impact Basins are given by:

ES-4WWW

where

WWW ≡ width of basin, WW.W ft

*Quantities of steel and concrete tabulated were obtained from sheet 1 of each ES-drawing. These quantities are approximate since quantities vary with pipe diameter.

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN UNIT	STANDARD DWG. NO. ES- 186 SHEET 1 OF 1 DATE 5 - 70